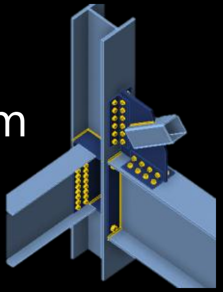
Bridge & Infrastructure Design with AASHTO: New Concrete Workflows in IDEA StatiCa v26.0

IDEA StatiCa®

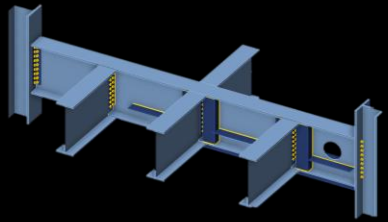
Connection

Design all steel connections from standard to complex joints



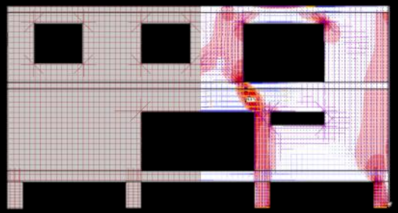
Member

Critical Beam and column design



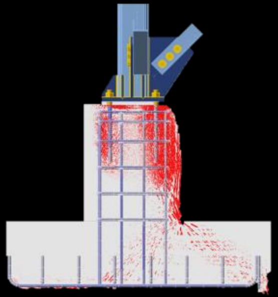
Detail

Replace STM when designing:
Transfer beams
Shear walls
Corbels
Walking columns



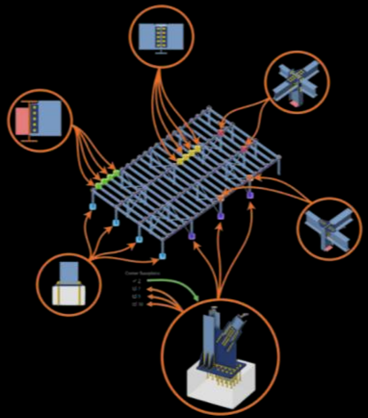
Connection + Detail

Complete base plate workflow including steel and concrete reinforcement design to avoid concrete breakout



Checkbot

Integration of 3rd party apps analysis models or BIM models with IDEA StatiCa applications



AGENDA

Design of concrete structures

Transportation structures with IDEA StatiCa

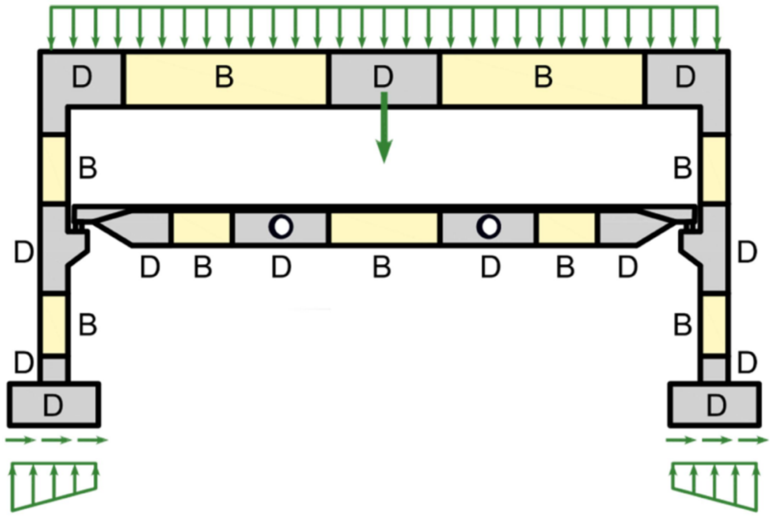
Overview of Version 26

Q&A session

STRUCTURAL DESIGN OF CONCRETE STRUCTURES

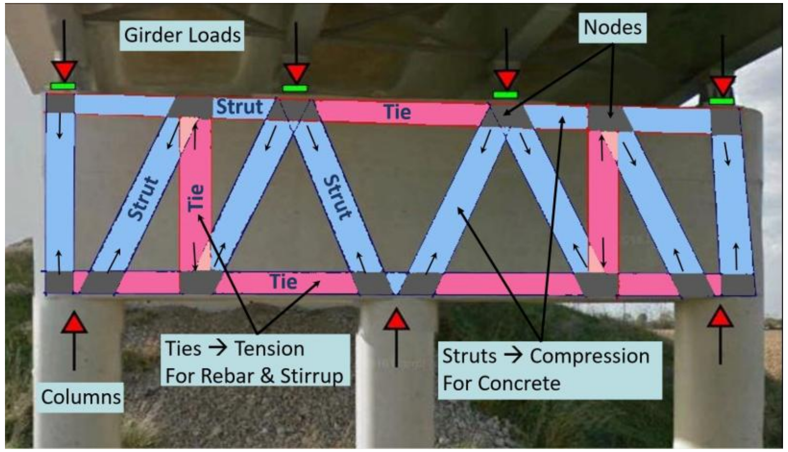
B-Regions: sections of the structure that can be designed with beam theory

D-Regions: Discontinuity regions where stress flow is unknown. Where traditional beam theory becomes unreliable.



DISCONTINUITY REGIONS= STRUT&TIE METHOD

Design codes (ACI, AASHTO) provide guidelines to use strut and tie method for the design of D-Regions



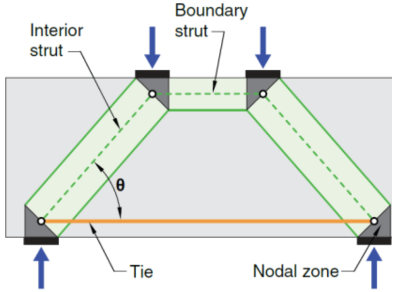


Fig. R23.2.1—Description of strut-and-tie model.

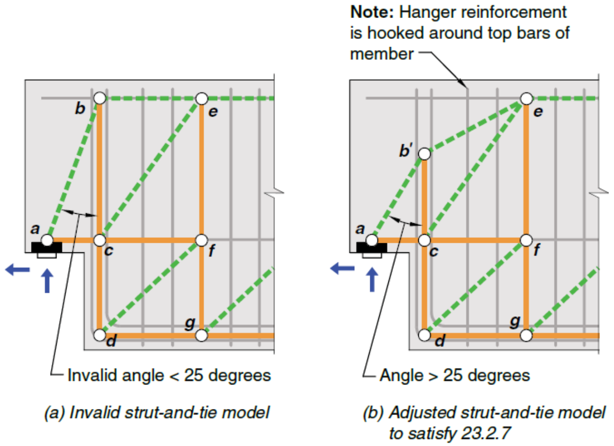


Fig. R23.2.7—Strut and-tie model of dapped connection illustrating adjustment to comply with 23.2.7.

COMMENTARY

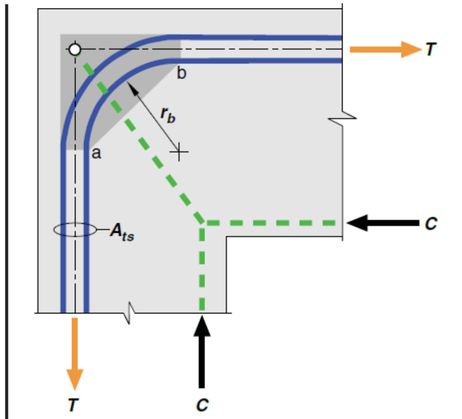
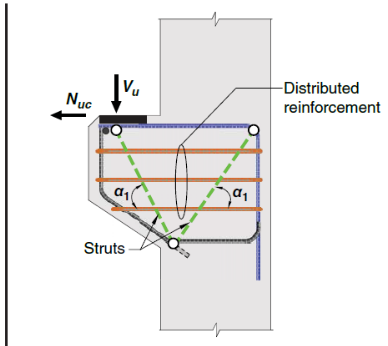


Fig. R23.10.4—Curved-bar node with two layers of reinforcement (nodal zone is shaded).



Distributed reinforcement crossing interior struts. Note that α_1 is different for the two struts above; the minimum distributed reinforcement ratio is controlled by the smaller angle α_1.

Fig. R23.5.1—Distributed reinforcement crossing interior struts.

STRUT&TIE

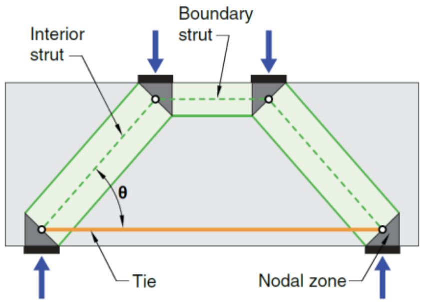


Fig. R23.2.1—Description of strut-and-tie model.

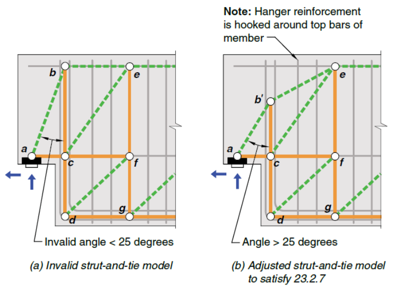
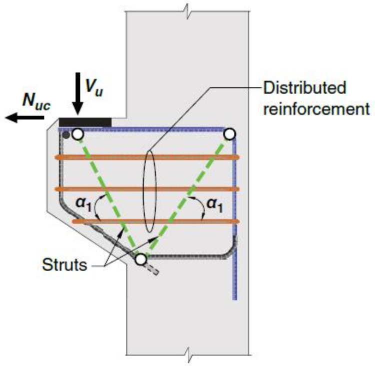
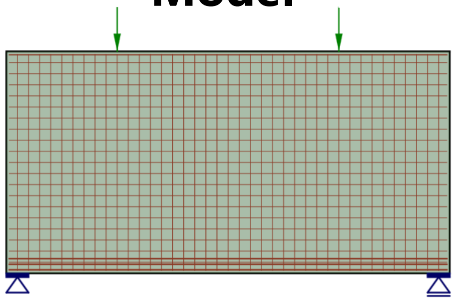


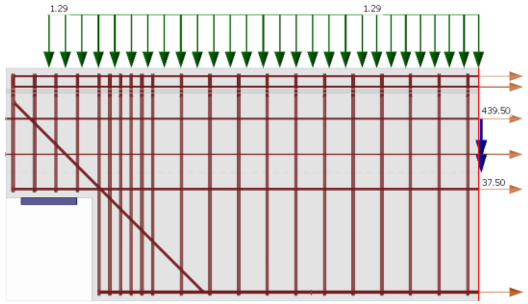
Fig. R23.2.7—Strut and-tie model of dapped connection illustrating adjustment to comply with 23.2.7.

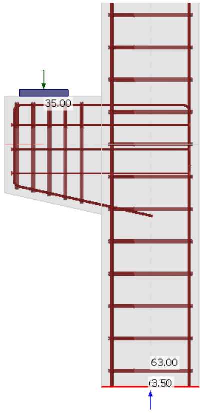
COMMENTARY



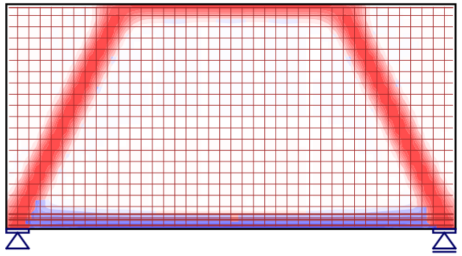
Model

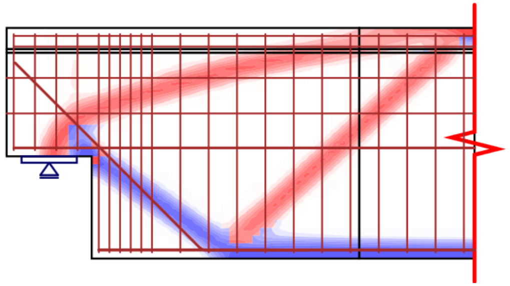


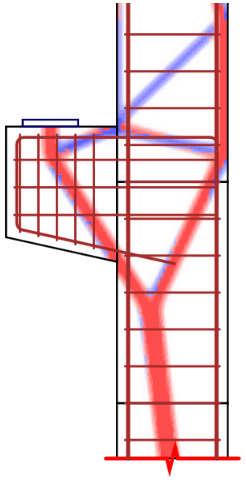




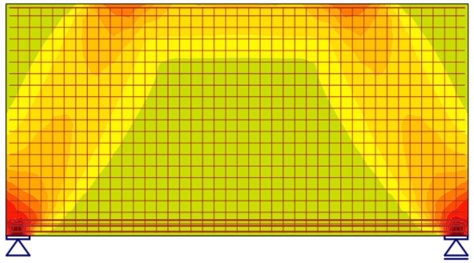
Design tools

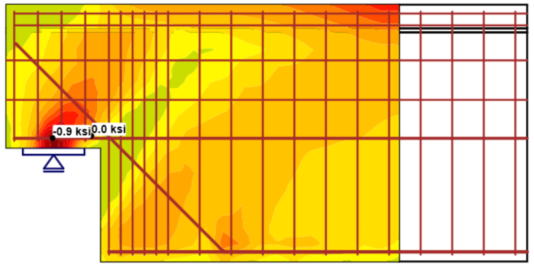


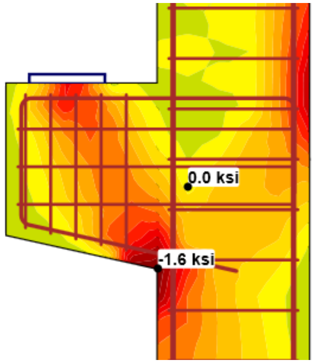




Stresses
(Concrete and rebar)







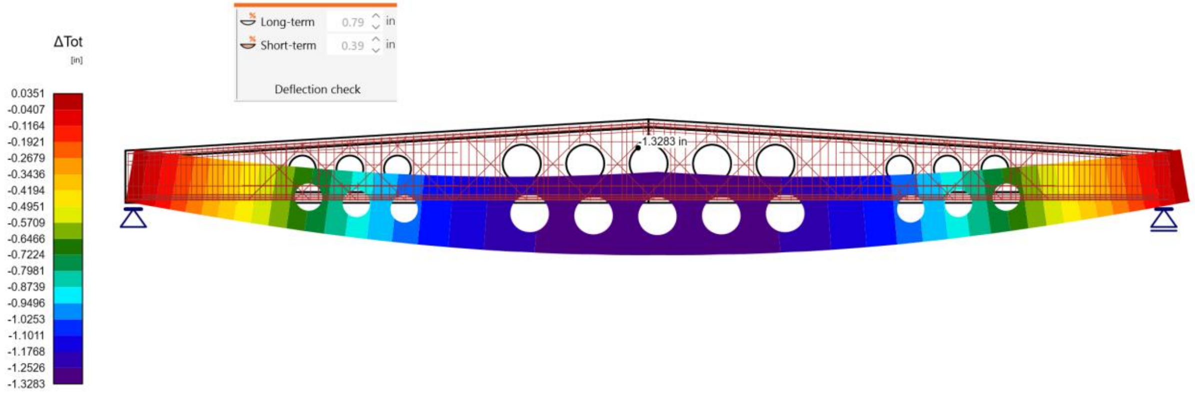
~~STRUT&TIE~~

Fig. R23.2.1—Description of strut-and-tie model.

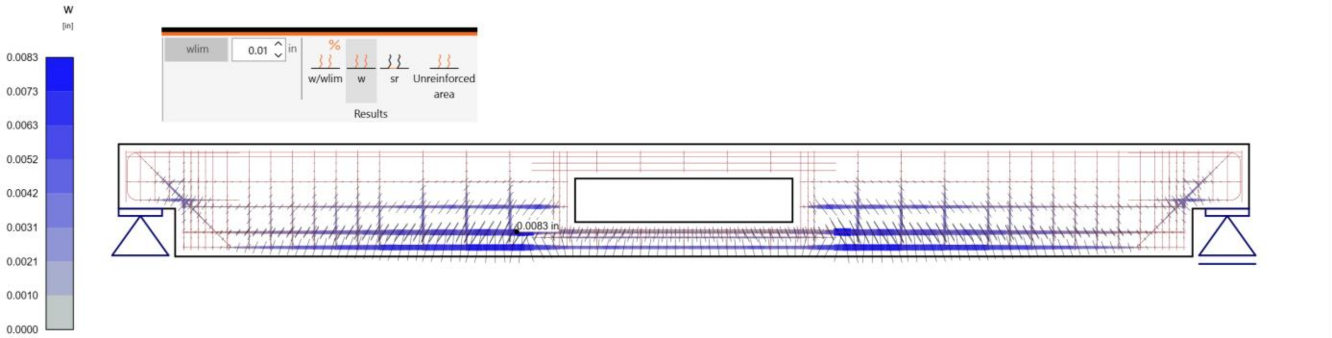
Fig. R23.2.7—Strut-and-tie model of dapped connection illustrating adjustment to comply with 23.2.7.

COMMENTARY

Deflections



Crack width



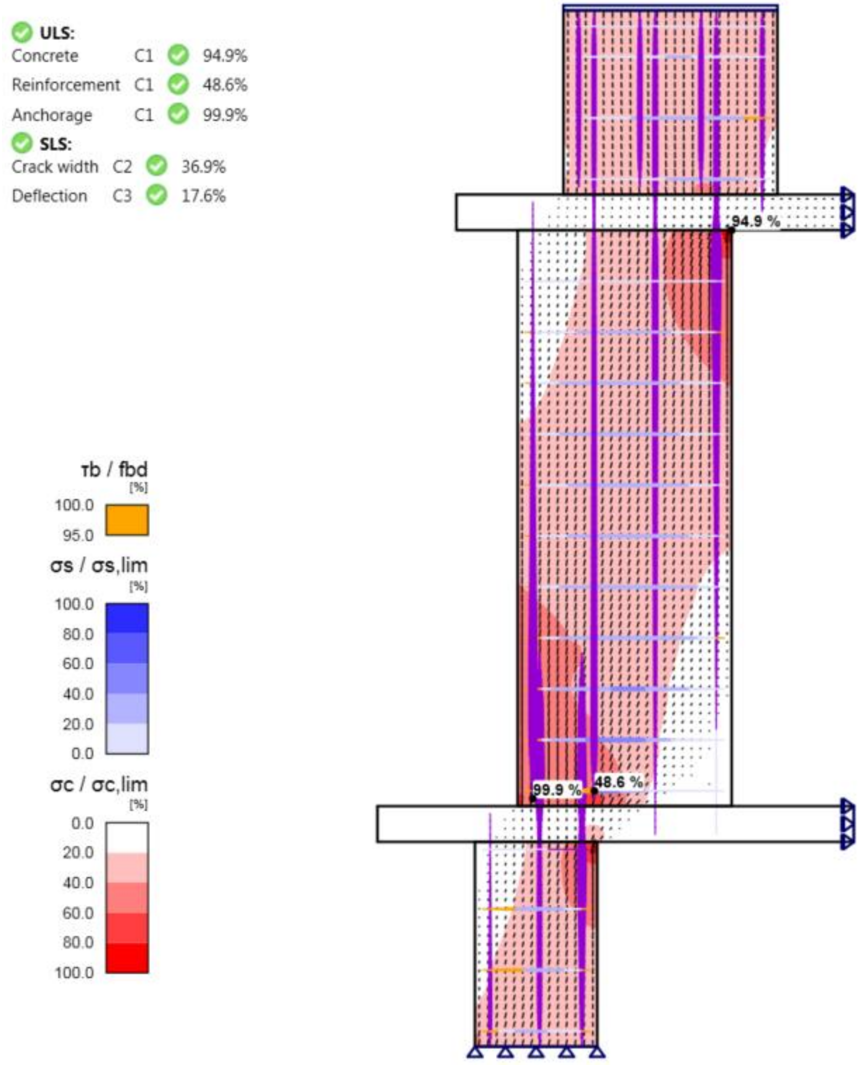
IMEG – WALKING COLUMNS

IMEG used Detail 2D to model as-built walking columns

Model was used to:

- ✓ Compare results with **ACI 318-14** strut and tie hand calculations
- ✓ Verify load transmission/bearing through floor
- ✓ Verify kick forces applied to floors from column walks
- ✓ Determine tension splitting zones from bottle struts in column walks to verify extents of carbon fiber reinforcement

Case study



IDEA StatiCa®

POLL

D-REGIONS – AASHTO LRFD BRIDGE DESIGN SPECIFICATION

distance between the extreme compression fiber and the centroid of the primary longitudinal reinforcement.

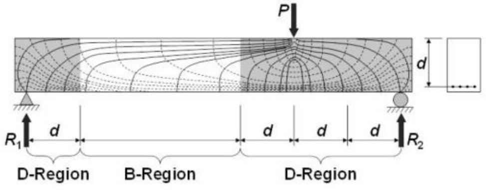


Figure 5.5.1.2.1-1— Stress Trajectories within B- and D-Regions of a Flexural Member (adapted from Birrcher et al., 2009)

D-Regions shall be taken to encompass locations with abrupt changes in geometry or concentrated forces. Based upon St. Venant's principle, D-Regions may be assumed to span one member depth on either side of the discontinuity in geometry or force.

Where the effective depth changes along the component the length of the D-Regions should be varied accordingly.

stress can be assumed at approximately one member depth from a load or geometric discontinuity. In other words, a nonlinear stress distribution exists within one member depth from the location where the discontinuity is introduced (Schlaich et al., 1987). D-Regions are therefore assumed to extend approximately a distance d from the applied load and support reactions in Figure 5.5.1.2.1-1. In the case of the reaction at an interior support, the disturbed region extends a distance d on each side of the reaction.

B-Regions occur between D-Regions, as shown in Figure 5.5.1.2.1-1. Plane sections are assumed to remain plane within B-Regions according to the primary tenets of beam theory, implying that a linear distribution of strains occurs through the member depth. The beam is therefore dominated by sectional behavior, and design can proceed on a section-by-section basis (i.e., sectional design). For the flexural design of a B-Region, the compressive stresses (represented by solid lines in Figure 5.5.1.2.1-1) are conventionally assumed to act over a rectangular stress block, while the tensile stresses (represented by dashed lines) are assumed to be carried by the longitudinal steel reinforcement.

5.8.2.3—Factored Resistance

The factored resistance, P_r, of a node face and ties shall be taken as that of axially loaded components:

$$P_r = \phi P_n \qquad (5.8.2.3\text{-}1)$$

where:

ϕ = resistance factor for tension or compression, specified in Article 5.5.4.2, as appropriate

P_n = nominal resistance of a node face or tie (kip)

5.8.2.4—Proportioning of Ties

5.8.2.4.1—Strength of Tie

The nominal resistance of a tie in kips shall be taken as:

$$P_n = f_y A_{st} + A_{ps}\left[f_{pe} + f_y\right] \qquad (5.8.2.4.1\text{-}1)$$

where:

f_y = yield strength of nonprestressed longitudinal reinforcement (ksi)

A_{st} = total area of longitudinal nonprestressed reinforcement (in.^{2})

A_{ps} = area of prestressing steel (in.^{2})

f_{pe} = effective stress in prestressing steel (ksi)

The sum of f_{pe} and f_y in Eq. 5.8.2.4.1-1 shall not be taken greater than the yield strength of the prestressing steel.

C5.8.2.4.1

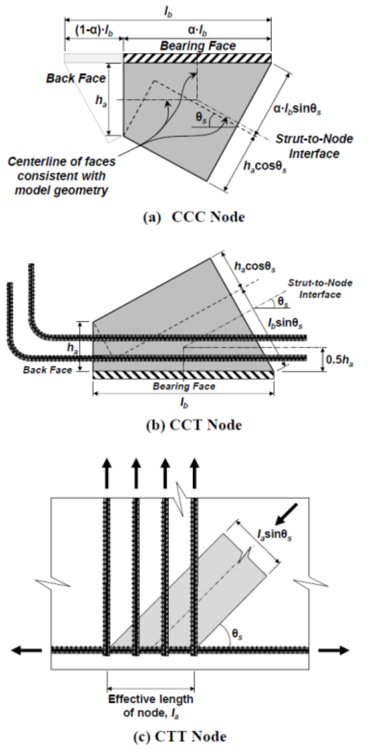
The second term of the equation for P_n is intended to ensure that the prestressing steel does not reach its yield point, thus a measure of control over unlimited cracking is maintained. It does, however, acknowledge that the stress in the prestressing elements will be increased due to the strain that will cause the concrete to crack. The increase in stress corresponding to this action is arbitrarily limited to the same increase in stress that the nonprestressed reinforcement will undergo. If there is no nonprestressed reinforcement, f_y may be taken as 60.0 ksi in the second term of Eq. 5.8.2.4.1-1.

5.8.2.4.2—Anchorage of Tie

The tie reinforcement shall be anchored to transfer the tension force therein to the node regions of the truss in accordance with the requirements for development of reinforcement as specified in Articles 5.9.4.3 and

C5.8.2.4.2

The ties must be properly anchored to ensure that the tie force can be fully developed and that the structure can achieve the resistance assumed by the STM. For a tie to be properly anchored at a nodal region, the yield



IDEA STATICA NOW SUPPORTS AASHTO

Sample projects

AASHTO Material models

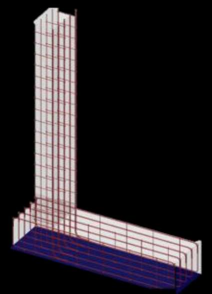
Stress-strain diagrams for serviceability

Resistance load factors (general approach to the D-regions)

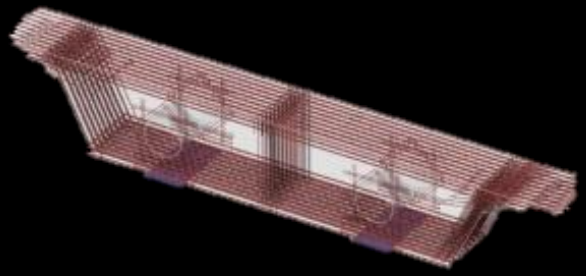
Strength limit state checks (material utilization ratio, bond stress)

Service limit state checks (short and long term)

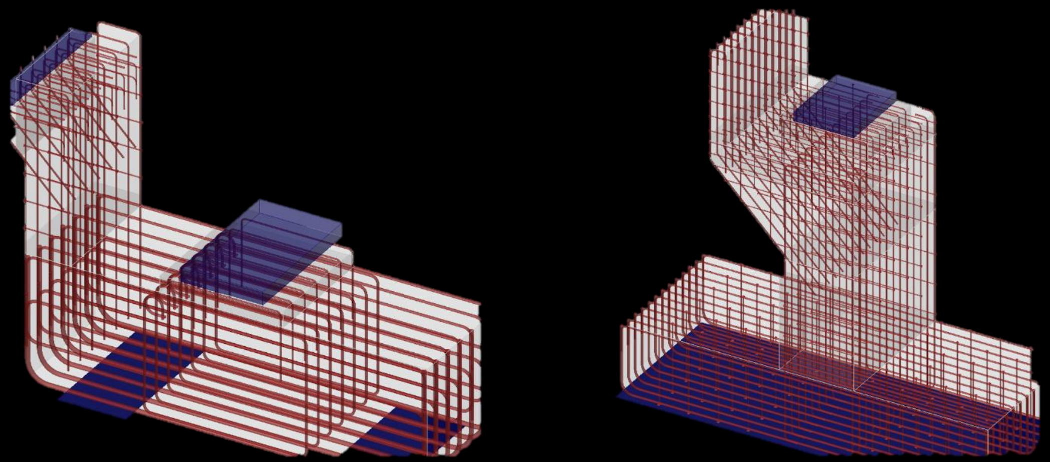
Deflection, Crack Width



Retaining walls



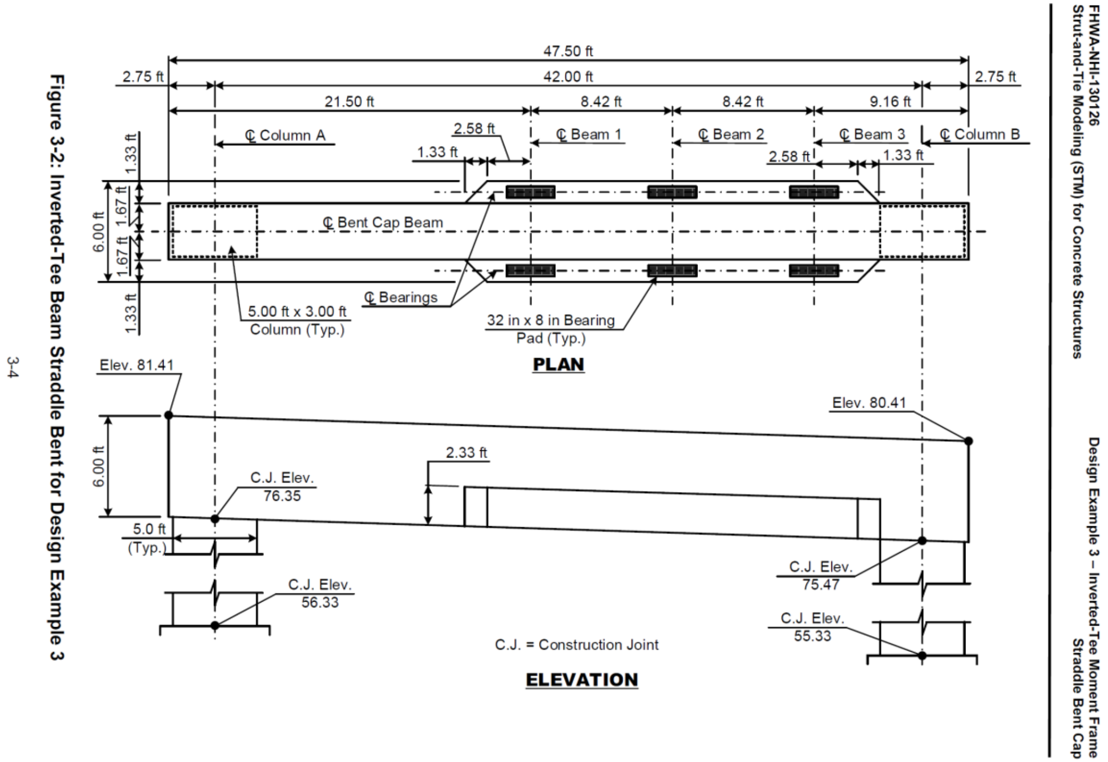
Box girder Diaphragms



Bridge sub-structure details

INVERTED-TEE MOMENT FRAME STRADDLE BENT CAP

The inverted-tee bent cap beam is part of a moment frame straddle bent, which will carry a **flyover ramp over a highway below.**



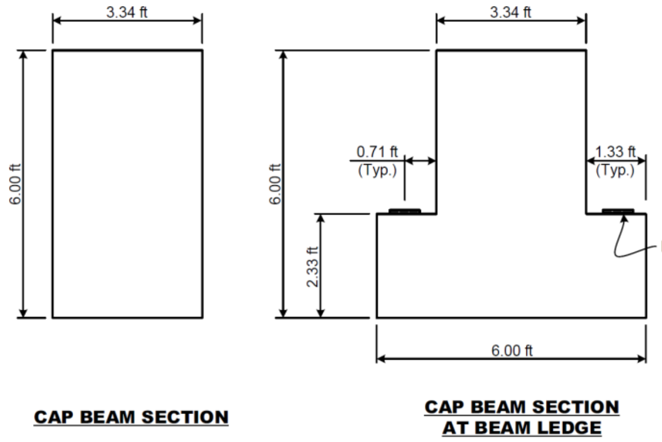


Figure 3-1: Typical Sections of Straddle Bent Cap Beam

Colorito, A., Wilson, K., Bayrak, O., and Russo, F. (2017). "Strut-and-Tie Modeling (STM) for Concrete Structures, Design Examples. FHWA-NHI-17-071, NHI Course No. 130126." FHWA, Washington, DC

INVERTED-TEE MOMENT FRAME STRADDLE BENT CAP

- This design example requires the use of **global and local strut-and-tie models** to fully model the flow of forces within the cap beam.
- *f'c* =6.0 ksi
- *fy*=60.0 ksi

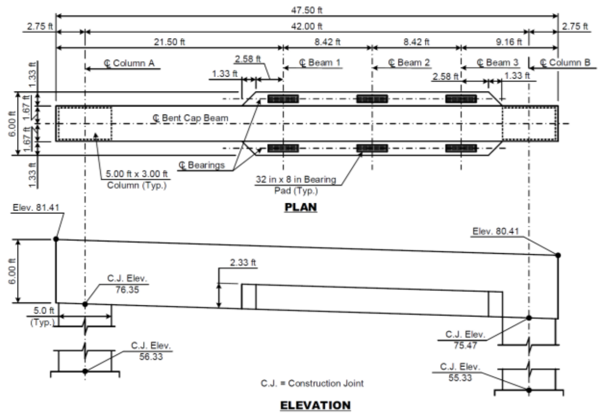


Figure 3-2: Inverted-Tee Beam Straddle Bent for Design Example 3

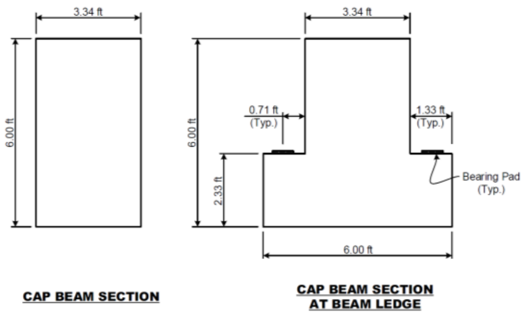


Figure 3-1: Typical Sections of Straddle Bent Cap Beam

LOAD ANALYSIS

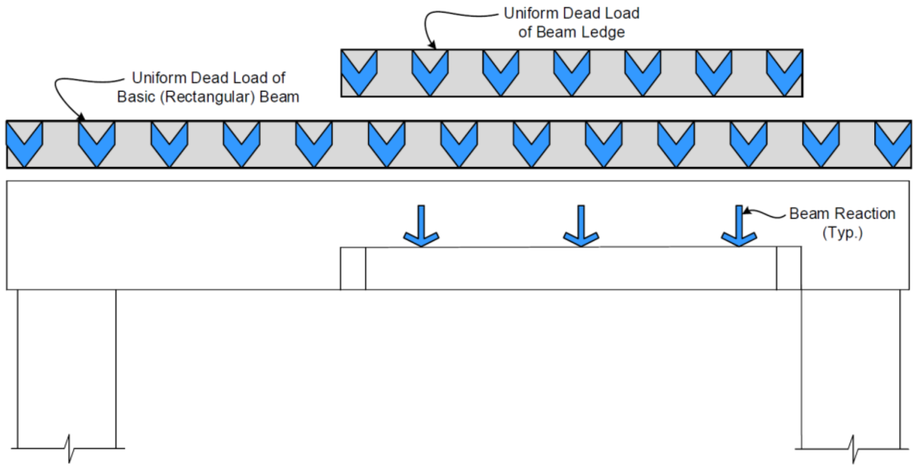
Detail App load comb setup:

Strength combination=

1.25xSelf weight

+

Factored beam loads



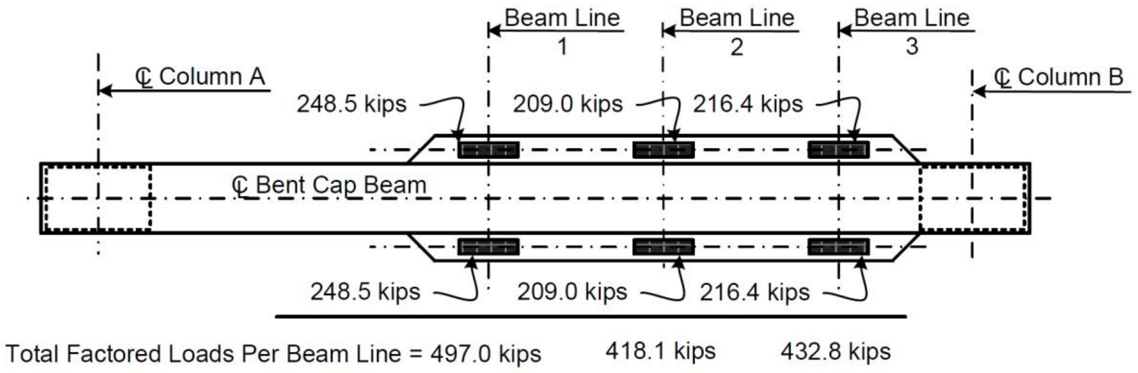
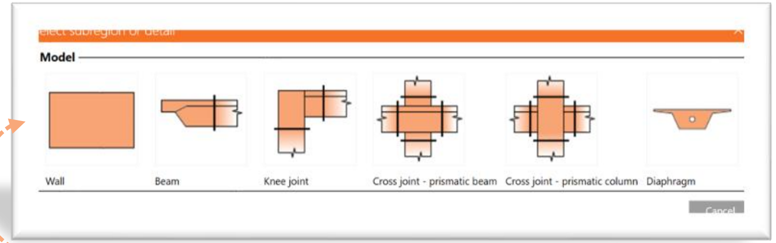
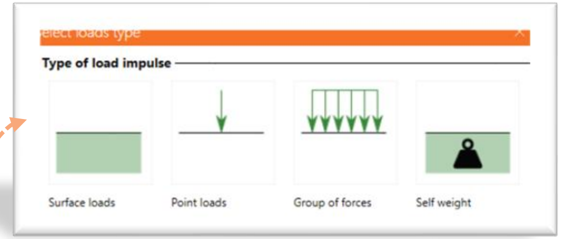
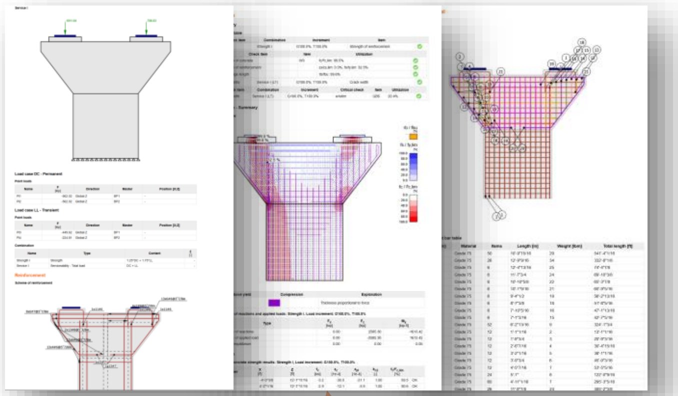


Figure 3-4: Factored Beam Loads per Beam Line

STEP-BY-STEP PROCESS



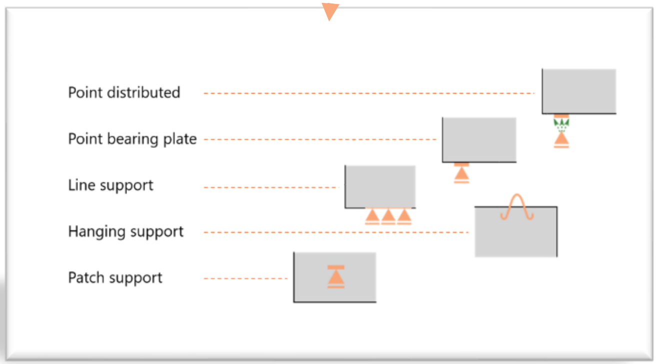


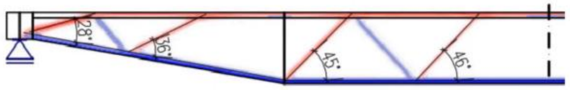


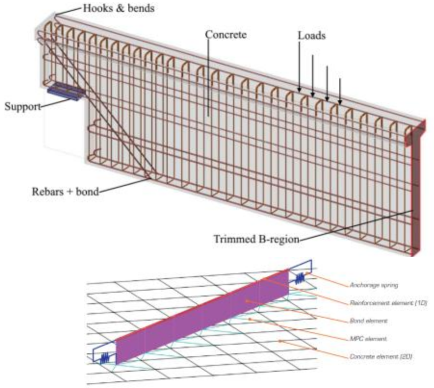
Linear analysis

✓ NON-Linear analysis

1. Set up the **geometry** (select general wall section or beam element)
2. Set up the **<u>supports</u>**
3. Set up the <u>load cases and load combinations</u> (strength and serviceability)
4. Run **<u>topology optimization</u>**
5. Pre-design steel **<u>reinforcement</u>**
6. Reinforcement design iterations
7. **<u>Report</u>**



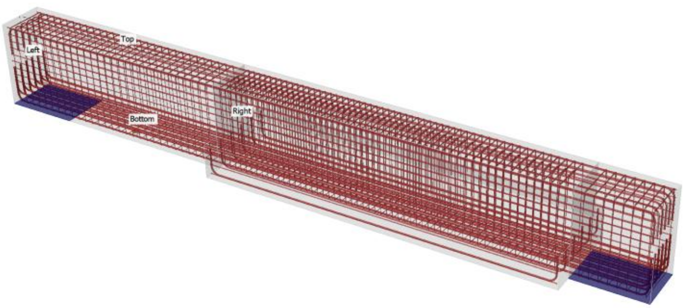




IDEA StatiCa®

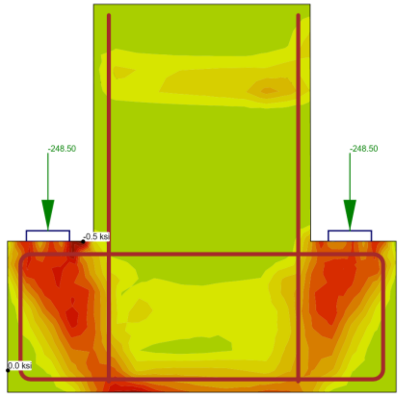
MODELS PREPARED

Frame as beam element



Frame as wall element

Section of the inverted tee (ledge beam)



SUMMARY

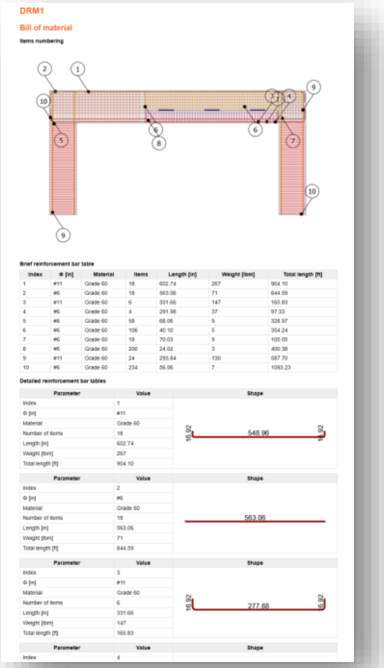
Verify and prove your strut and tie model's w/topology optimization

Comply with AASHTO Specs for **bridge concrete details**

Design for **strength and service** combinations:

- ✓ Concrete compressive strength
- ✓ Steel reinforcement strength and development length
- ✓ Deflection and crack width

Deliver complete calculation packages: **bill of material and CAD details**



DRM1

Bill of material

Items numbering

Brief reinforcement bar table

Index	Φ [in]	Material	Items	Length [in]	Weight [lbm]	Total length [ft]
1	#11	Grade 60	18	602.74	267	904.10
2	#6	Grade 60	18	563.06	71	844.59
3	#11	Grade 60	6	331.66	147	165.83
4	#6	Grade 60	4	291.98	37	97.33
5	#6	Grade 60	58	68.06	9	328.97
6	#6	Grade 60	106	40.10	5	354.24
7	#6	Grade 60	18	70.03	9	105.05
8	#6	Grade 60	200	24.02	3	400.38
9	#11	Grade 60	24	293.84	130	587.70
10	#6	Grade 60	234	56.06	7	1093.23

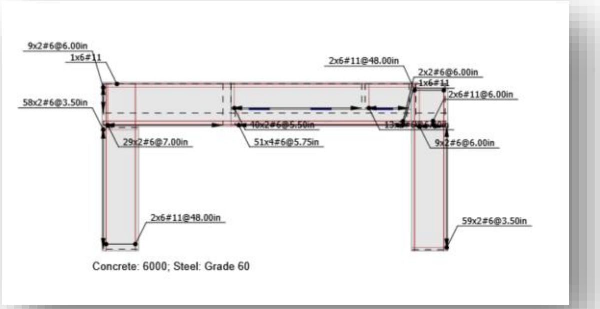
Detailed reinforcement bar tables

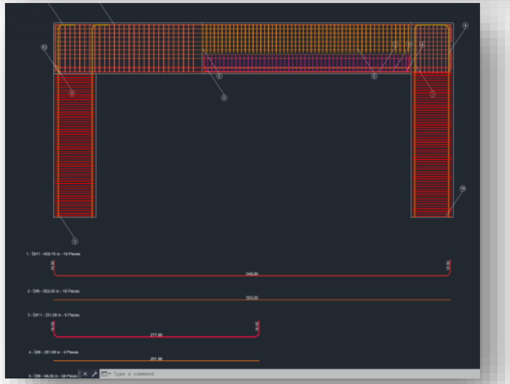
Parameter	Value	Shape
Index	1	16.92 / 548.96 / 16.92
Φ [in]	#11	
Material	Grade 60	
Number of items	18	
Length [in]	602.74	
Weight [lbm]	267	
Total length [ft]	904.10	

Parameter	Value	Shape
Index	2	563.06
Φ [in]	#6	
Material	Grade 60	
Number of items	18	
Length [in]	563.06	
Weight [lbm]	71	
Total length [ft]	844.59	

Parameter	Value	Shape
Index	3	16.92 / 277.88 / 16.92
Φ [in]	#11	
Material	Grade 60	
Number of items	6	
Length [in]	331.66	
Weight [lbm]	147	
Total length [ft]	165.83	

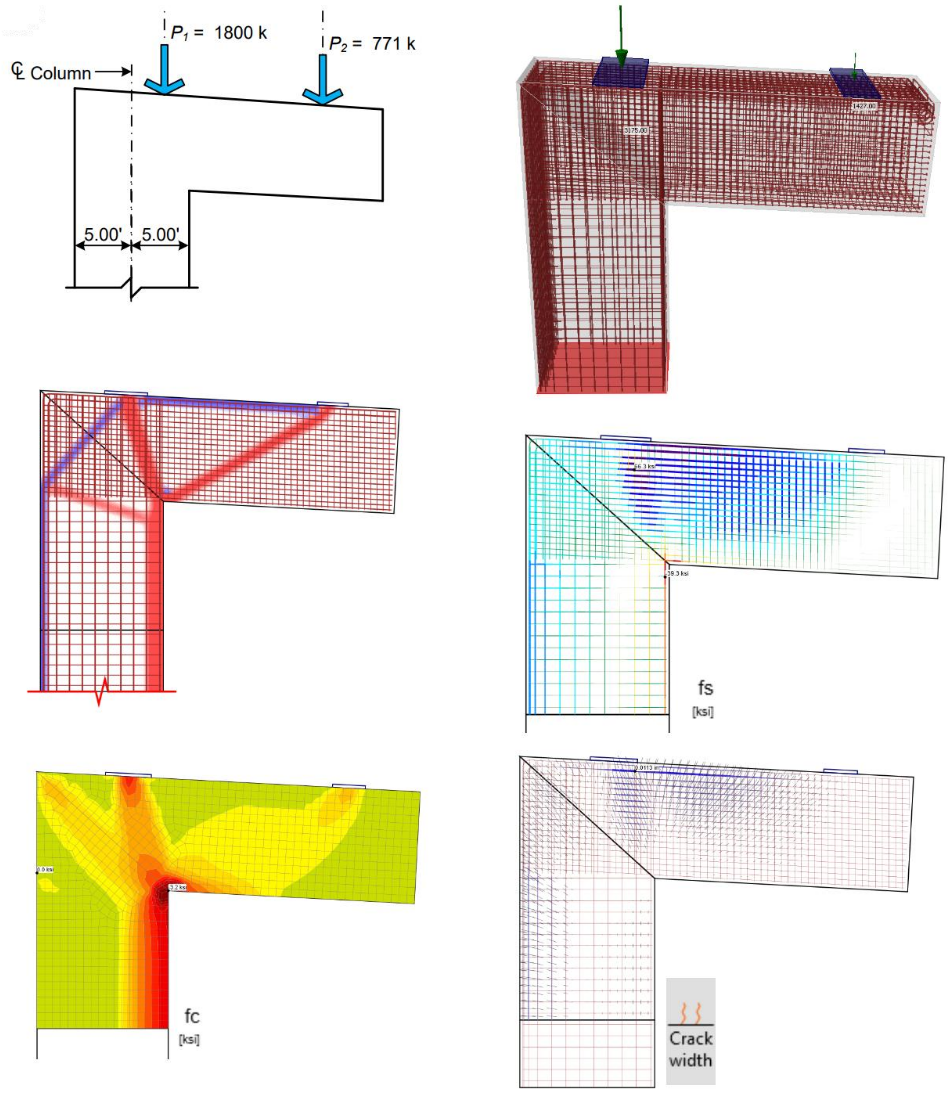
Parameter	Value	Shape
Index	4	





DOWNLOAD VERSION 26.0 NOW!

- AASHTO ready tutorials
  1. Cantilever bent cap
  2. Inverted-tee moment frame straddle bent cap

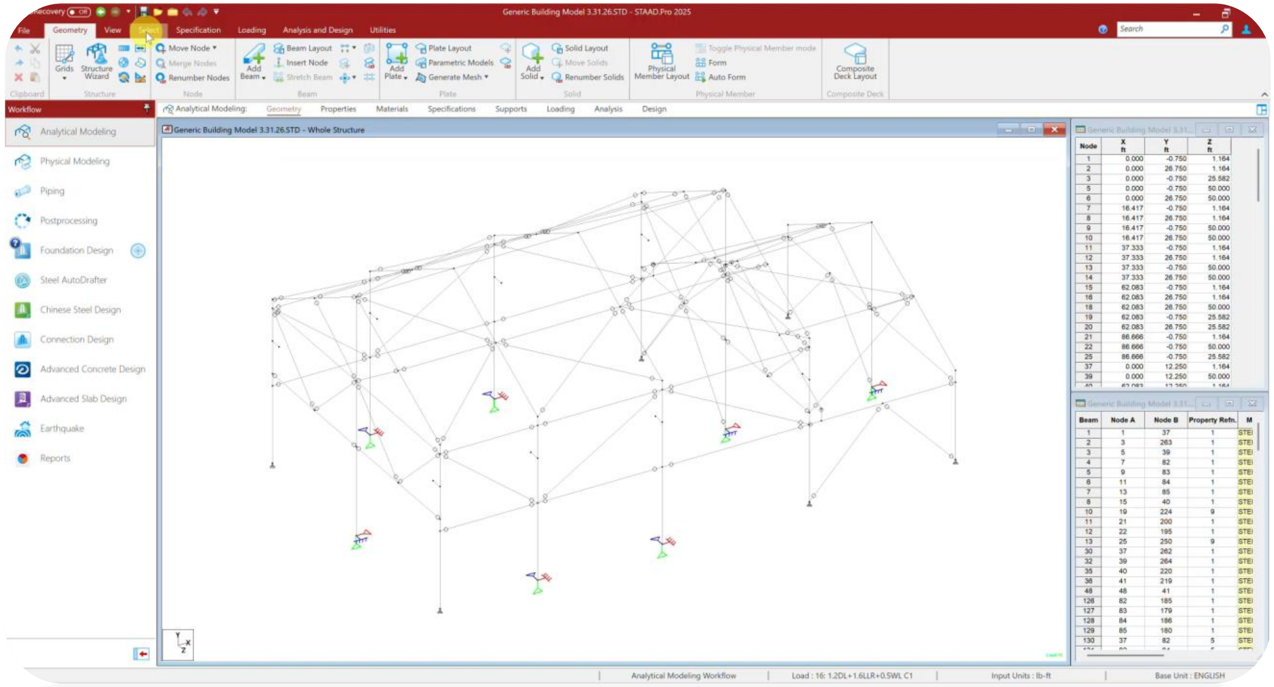


VERSION 26

- ❑ Checkbot 3D Scene improved
- ❑ Utilization ratio prediction for connections
- ❑ Detail 3D: Anchor checks, failing members explanation, surface support reactions
- ❑ Detail 3D model update from Connection app
- ❑ Complete solution for embedded plates

VERSION 26

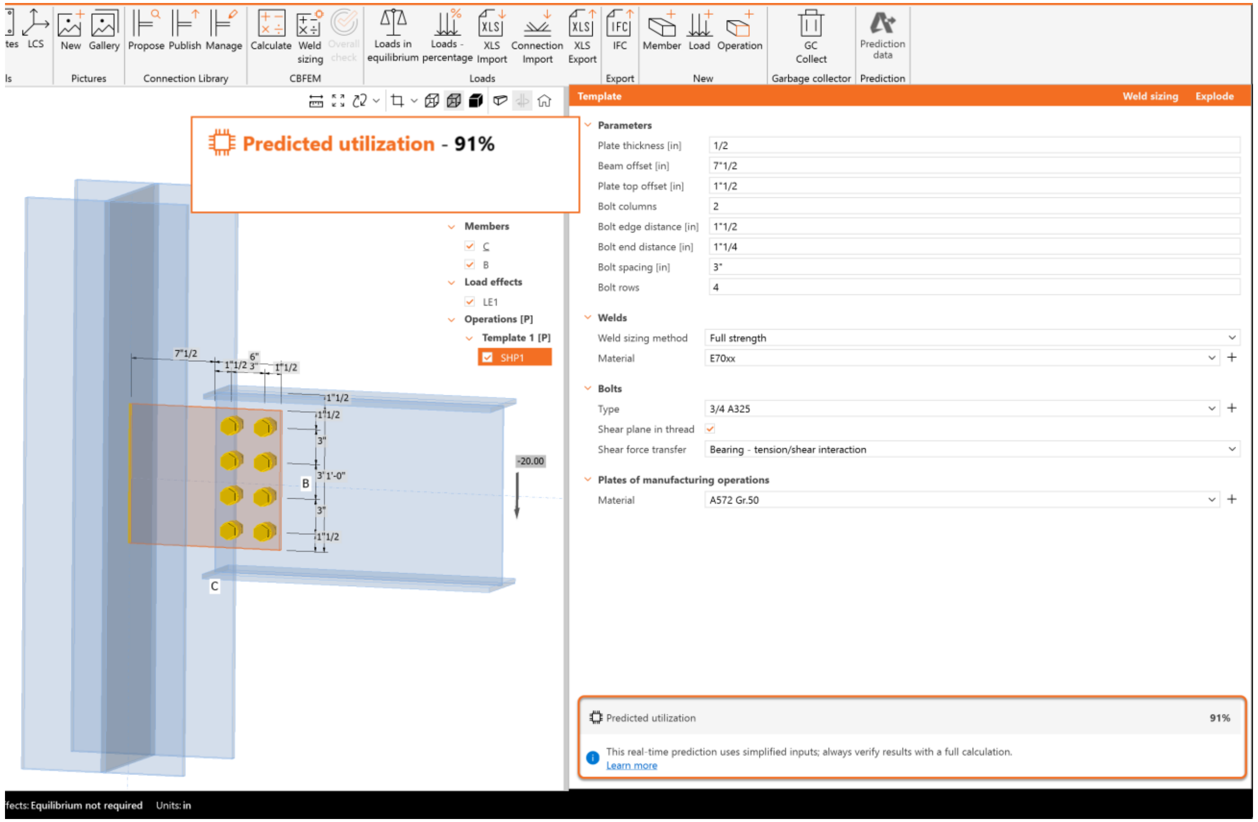
- ❑ Checkbot 3D Scene improved
- ❑ Utilization ratio prediction for connections
- ❑ Detail 3D: Anchor checks, failing members explanation, surface support reactions
- ❑ Detail 3D model update from Connection app
- ❑ Complete solution for embedded plates



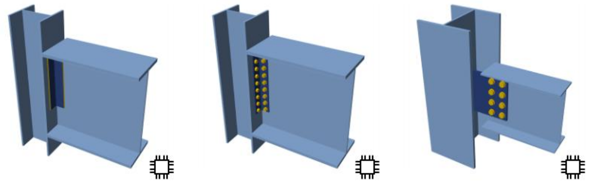
IDEA StatiCa®

VERSION 26

- ❑ Checkbot 3D Scene improved
- ❑ Utilization ratio prediction for connections
- ❑ Detail 3D: Anchor checks, failing members explanation, surface support reactions
- ❑ Detail 3D model update from Connection app
- ❑ Complete solution for embedded plates



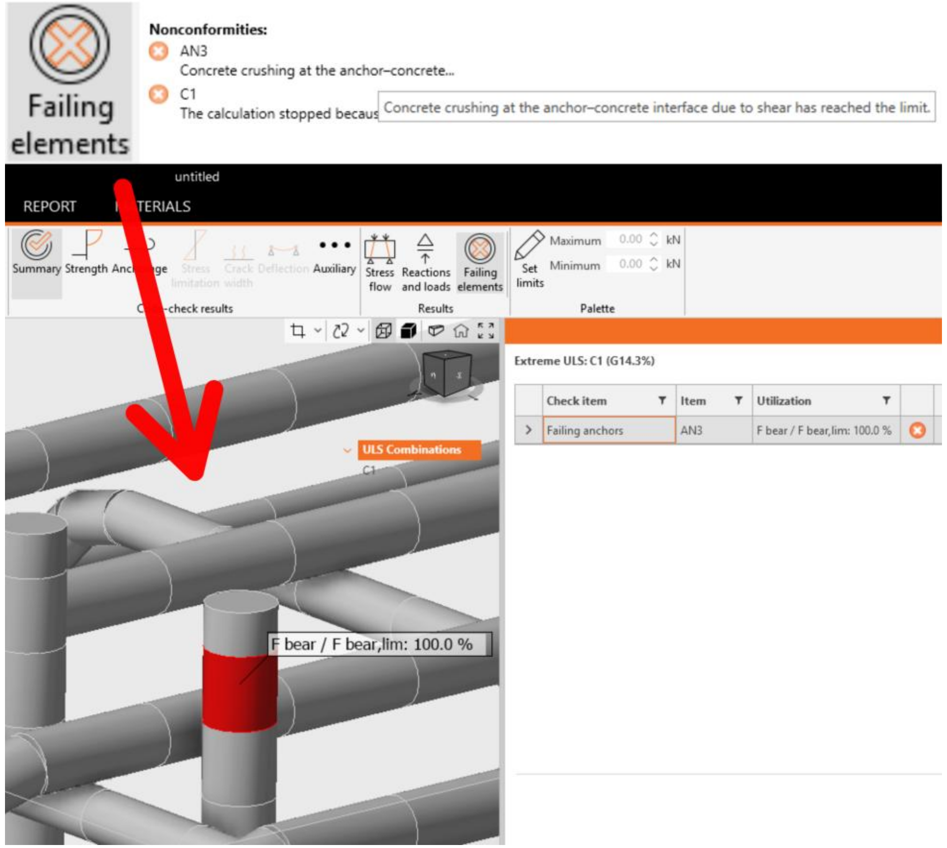
Utilization considers steel components, forces, welds, bolts



VERSION 26

- ❑ Checkbot 3D Scene improved
- ❑ Utilization ratio prediction for connections
- ❑ Detail 3D: Anchor checks, failing members explanation, surface support reactions
- ❑ Detail 3D model update from Connection app
- ❑ Complete solution for embedded plates

3D DETAIL



VERSION 26

- ❑ Checkbot 3D Scene improved
- ❑ Utilization ratio prediction for connections
- ❑ Detail 3D: Anchor checks, failing members explanation, surface support reactions
- ❑ Detail 3D model update from Connection app
- ❑ Complete solution for embedded plates

VERSION 26

- ❑ Checkbot 3D Scene improved
- ❑ Utilization ratio prediction for connections
- ❑ Detail 3D: Anchor checks, failing members explanation, surface support reactions
- ❑ Detail 3D model update from Connection app
- ❑ Complete solution for embedded plates