LOAD RATING TIMBER BENT CAPS USING BrDR SOFTWARE (A WORKAROUND APPROACH)

Vinacs (Murugesu) Vinayagamoorthy, Caltrans

AASHTOWare BrDR 7.4.0

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OUTLINE

- Brief California Facts
- Transverse Beam Cap Analysis Overview
- Existing BrDR Floor System modules
- Workaround to Floor System Modules to load rate Timber cap members
- An Example
- Concluding Remarks

BRIEF CALIFORNIA FACTS

- Caltrans Has 498 Timber Bridges
  - 12 Timber Trusses
  - 460 Timber Stringer Bridges (5 State Bridges)
  - 26 Bridges with Timber Approach Spans
  - Most of them are Local Agency Bridges
  - Load Rate Timber Stringers routinely
- Working Stress Method
  - In House Excel software used for rating
  - Just started to transition into LRFR
- Bent Caps are rated only if,
  - Deterioration is found, and/or
  - Supporting piles are damaged
  - MBE Article 6.1.5.2

BRDR TIMBER RATINGS' FEATURE

- Introduction of AASHTOWare Timber Engine to BrDR version 7.3.

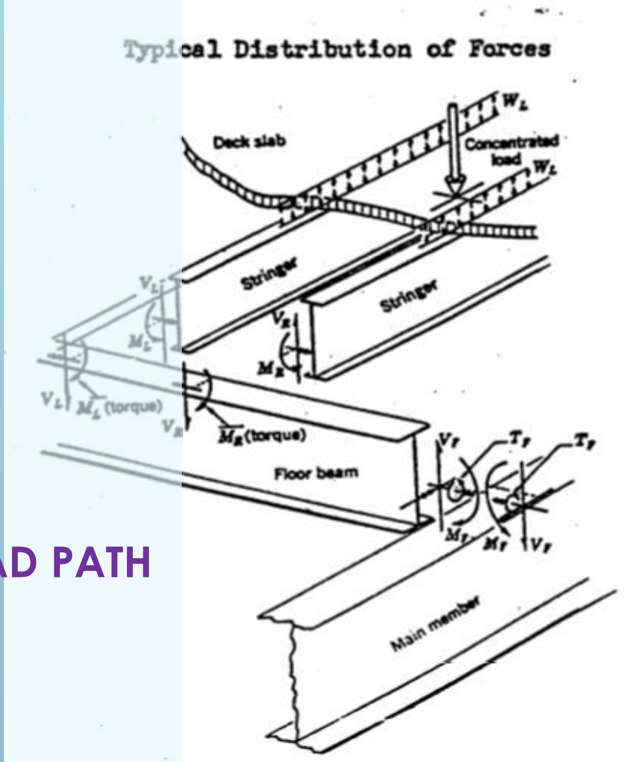
BrDR Timber Rating Capability

- Stringers
- ❌ NO Bent Caps

- Developed a Workaround for Timber CAPs
  - have both Stringers and Caps rated by the same software
  - Will be going over the workarounds

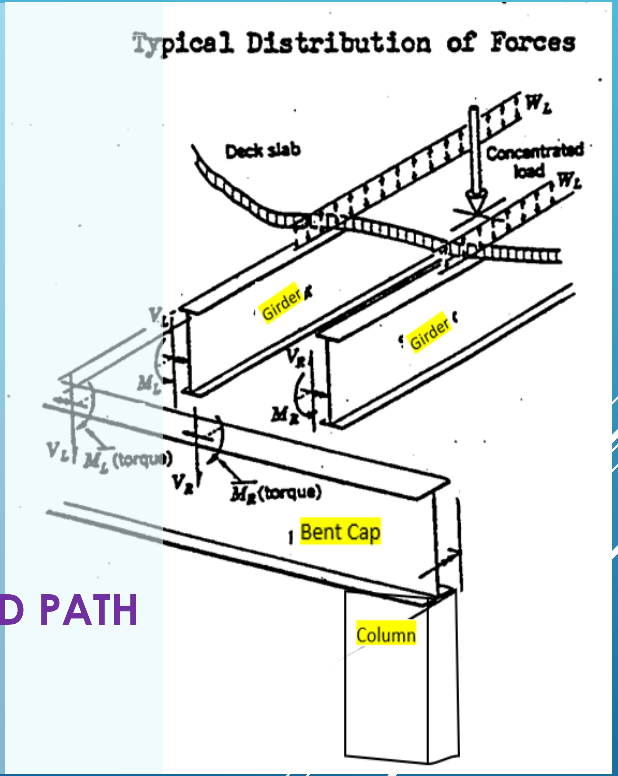
Load Path of a typical Girder System

- Deck
- Stringer/Girder (Longitudinal member)
- Floor beam (transverse member)
- Longitudinal Girder (Support to FB)



FLOOR BEAM LOAD PATH

- Deck
- Girders (Longitudinal member)
- Bent CAP (transverse member)
- Column (Support)



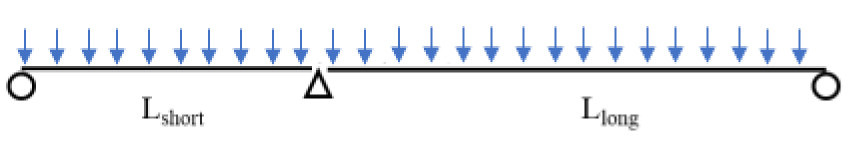
BENT CAP LOAD PATH

FLOOR BEAM vs BENT CAP ANALYSIS

- **Note that, The load factors and resistance factors are the same of Floor beam and Bent cap members.**

Establish Reaction at Cap

STEP 1: Using longitudinal analysis



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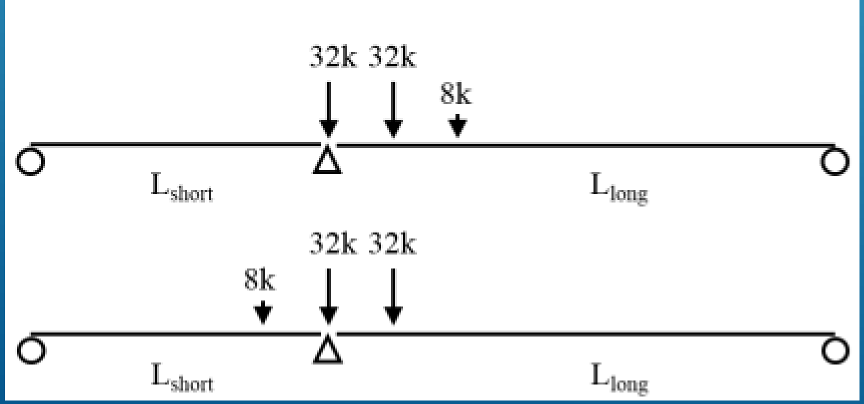
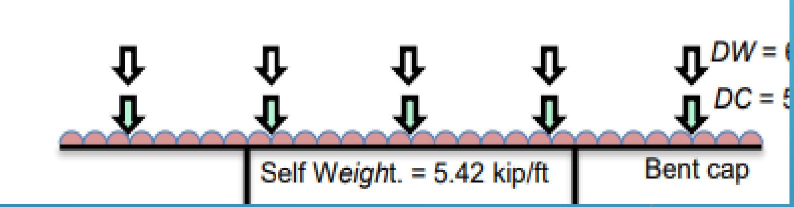
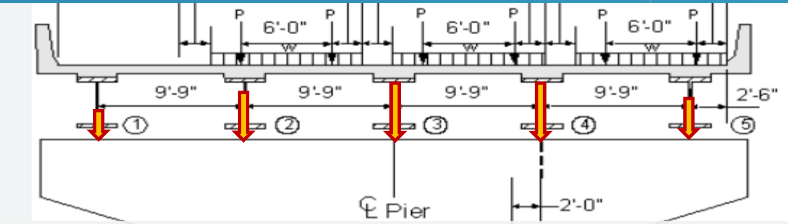


LL
Two Alternative Approaches

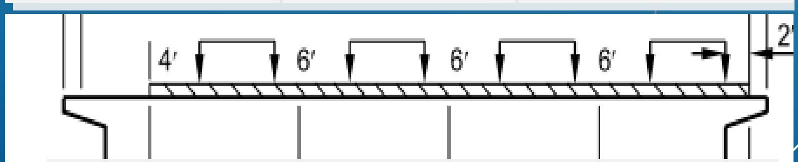
Establish Demand on the Cap

STEP 2: Using transversely spanning analysis





LL Reaction through Girders Approach (**BrDR**)



LL placed on Cap directly Approach (**Caltrans**)

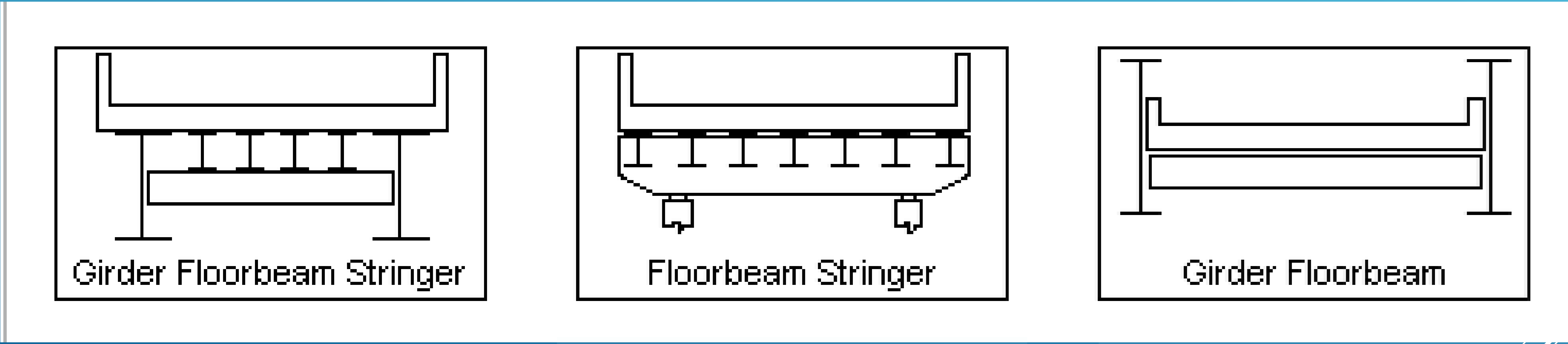
Since BrDR does this effectively for load-rating Floor beams, load rating of Caps can be performed, with **some work arounds**!

TRANSVERSE BEAM ANALYSIS

GFS System

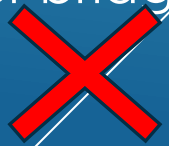
FS System

GF-System



- Preferred Choice

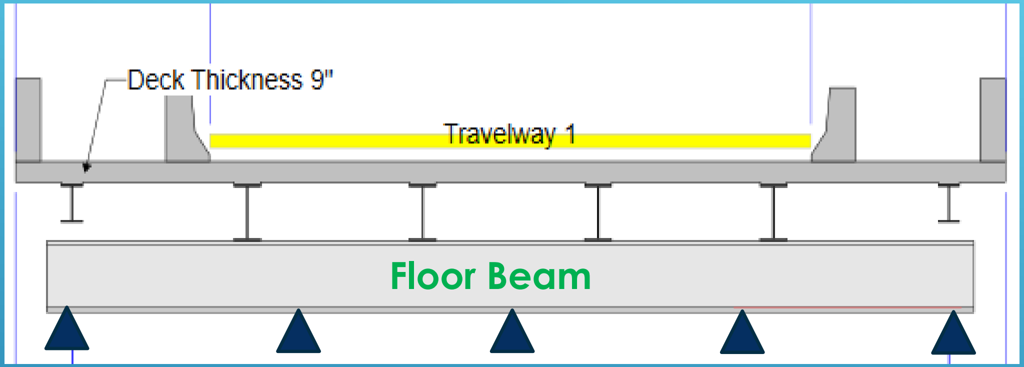
- Timber Bridges will always have stringers.
- CANNOT be used for timber bridges

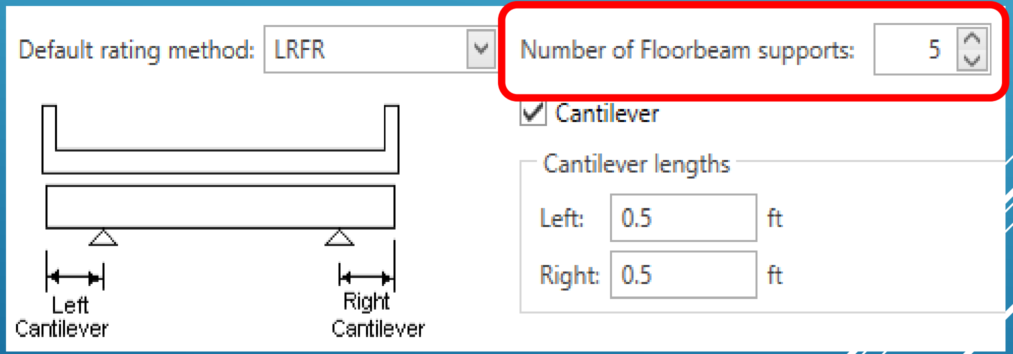


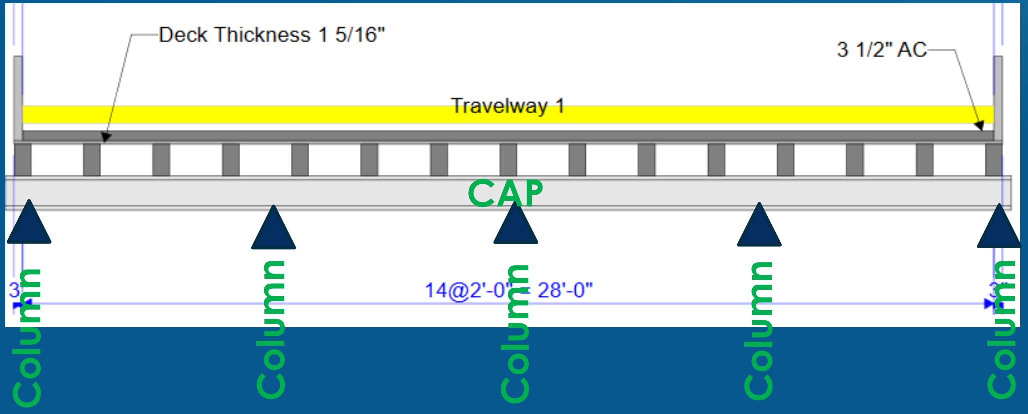
AASHTOWare BrDR FLOOR SYSTEM MODULES

FS (Floor beam Stringer) SYSTEM

- For Floor Beam Analysis
  - Deck (Concrete/Corrugated steel)
  - Steel Stringers
  - Steel Floor beam (Transversely spanning)
  - *Multiple Supports for floor beams*
  - Hinges are allowed on the Floor Beam



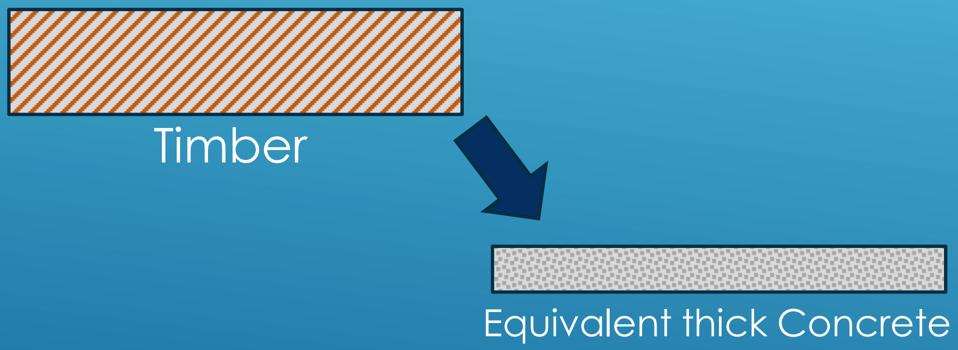




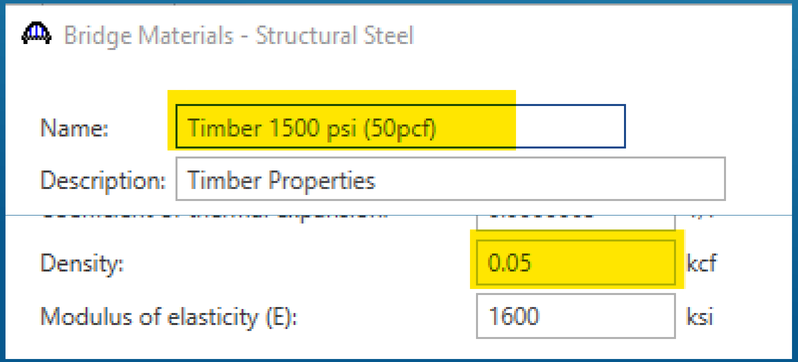
- For Bent Cap Analysis
  - Supports will be Columns
  - Floor Beams will be Bent Caps

LIMITATIONS

1. Deck Material to be **Concrete**



2. Stringer/FB/Girder are to be "**Steel**"


Bridge Materials - Structural Steel

Name:	Timber 1500 psi (50pcf)	
Description:	Timber Properties	
Density:	0.05	kcf
Modulus of elasticity (E):	1600	ksi

WORK AROUNDS

1. Timber Deck

- Equivalent Deck Thickness
  - Density of Concrete **150** lbs/cuft
  - Density of Timber is **50** lbs/cuft.
- So, Equivalent Deck thickness
  - = (**50**/**150**) x timber deck thickness
  - **6"** Timber deck = **2"** concrete deck

2. Steel Member

- User Defined Steel
  - Density **50** lbs/cuft
  - Elastic Modulus **1,600** ksi
    - Depends on the timber material

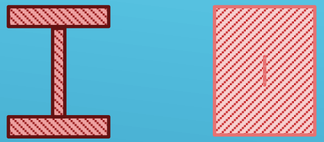
LIMITATIONS

3. **Shape**
   - Steel Member is I shape
   - Timber is Rectangular Shape

4. **Capacity**
   - Capacity based on steel specification is not applicable.
   - Allowable stress F_b
   - Shear capacity

WORK AROUNDS

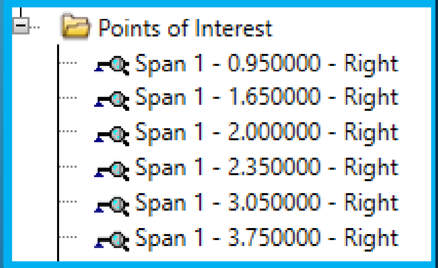
3. **Shape**
   - Enter Section as Plate Section
   - Set web thickness equal to flange width

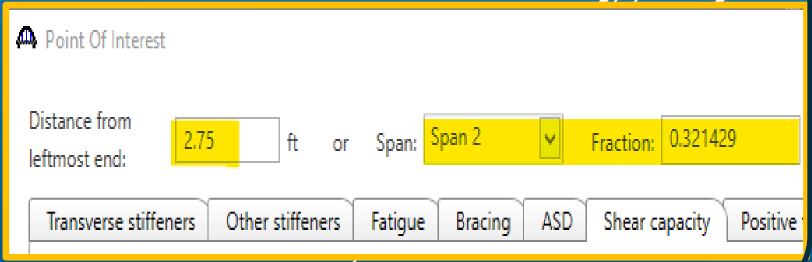


4. **Capacity**

- **Capacity Overwrite** at Pt of Interest
  - ALL 10^{th} points
  - Critical Shear locations
    - Within "d" distance pts,

      Enter a very large shear capacity





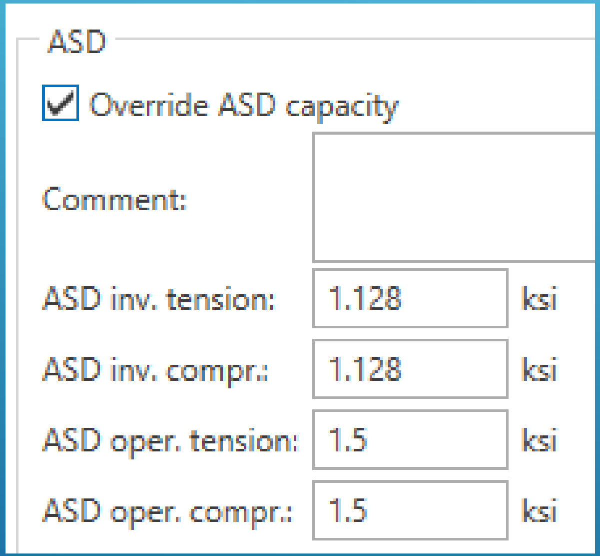
ASR CAPACITY OVERWRITE WORK AROUND

4. Capacity

- **Capacity Overwrite** at Pt of Interest
  - Inventory and Operating Flexural stress override

The allowable unit stress in bending shall be the tabulated stress adjusted by the applicable adjustment factors given in the following equation:

$$F_b' = F_b C_M C_D C_F C_V C_L C_f C_{fu} C_r \quad (13\text{-}2)$$

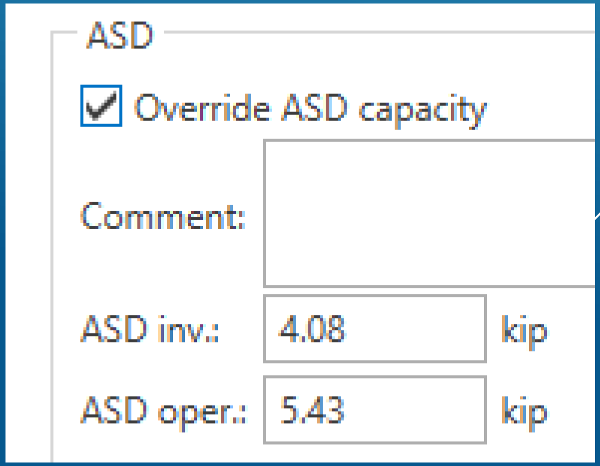


  - Inventory and Operating shear capacity override

$$f_v = \frac{3V}{2bd} \quad (13 - 9)$$

$$F_v' = F_v C_M C_D \quad (13\text{-}11)$$

$$V_c = (2/3)\ bd\ f_v$$



LRFR CAPACITY OVERWRITE WORK AROUND

4. Capacity

- **Capacity Overwrite** at Pt of Interest
  - **Strength I and Strength II Flexural Capacities**

$$F_b = F_{bo}\, C_{KF}\, C_M\, (C_F \text{ or } C_v)\, C_{fu}\, C_i\, C_d\, C_\lambda \qquad (8.4.4.1\text{-}1)$$

$$M_n = F_b\, S\, C_L \qquad (8.6.2\text{-}1)$$

$$M_r = \phi M_n \qquad (8.6.1\text{-}1)$$

Flexure .... $\phi = 0.85$
Shear .... $\phi = 0.75$

  - **Strength I and Strength II Shear Capacities**

$$F_v = F_{vo}\, C_{KF}\, C_M\, C_i\, C_\lambda \qquad (8.4.4.1\text{-}2)$$

$$V_n = \frac{F_v b d}{1.5} \qquad (8.7\text{-}2)$$

$$V_r = \phi V_n \qquad (8.7\text{-}1)$$

Positive flexural capacity | Negative flexural capacity

☑ Override LRFR capacity

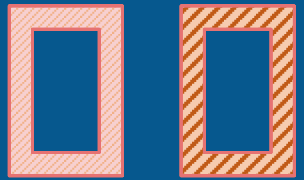
Limit state	Override	Moment capacity (kip-ft)	Tension capacity (ksi)	Compr. capacity (ksi)	Phi
STRENGTH-I	☑	54.43	3.318	3.318	0.85
STRENGTH-II	☑	54.43	3.318	3.318	0.85
SERVICE-II	☐				
FATIGUE	☐				

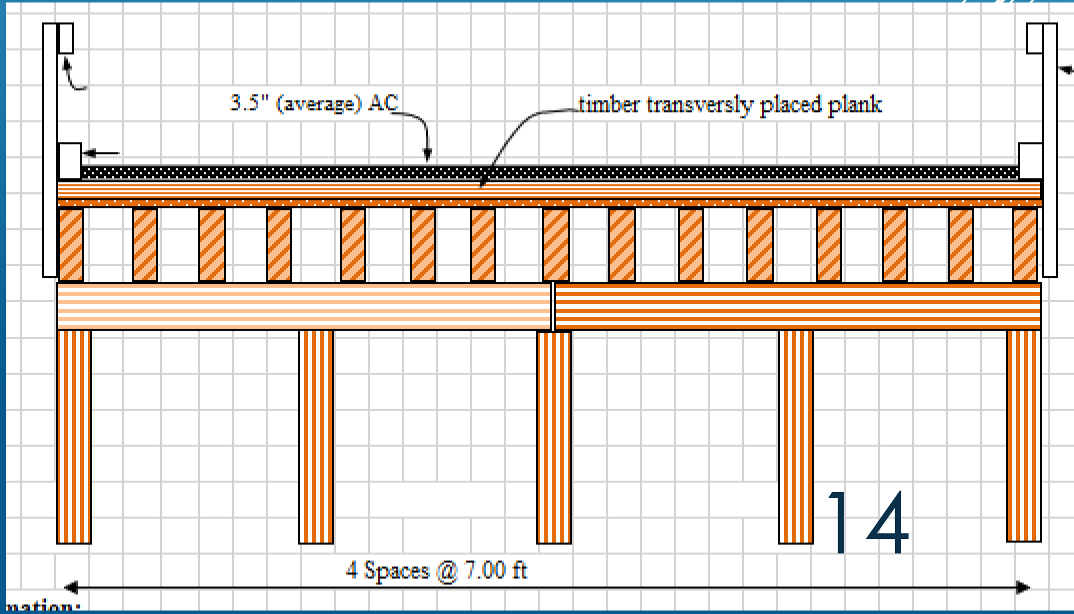
Shear capacity

Limit state	Override	Capacity (kip)	Phi
STRENGTH-I	☑	13.6	0.75
STRENGTH-II	☑	13.6	0.75
SERVICE-II	☐		
FATIGUE	☐		

EXAMPLE – TWO SPAN TIMBER BRIDGE

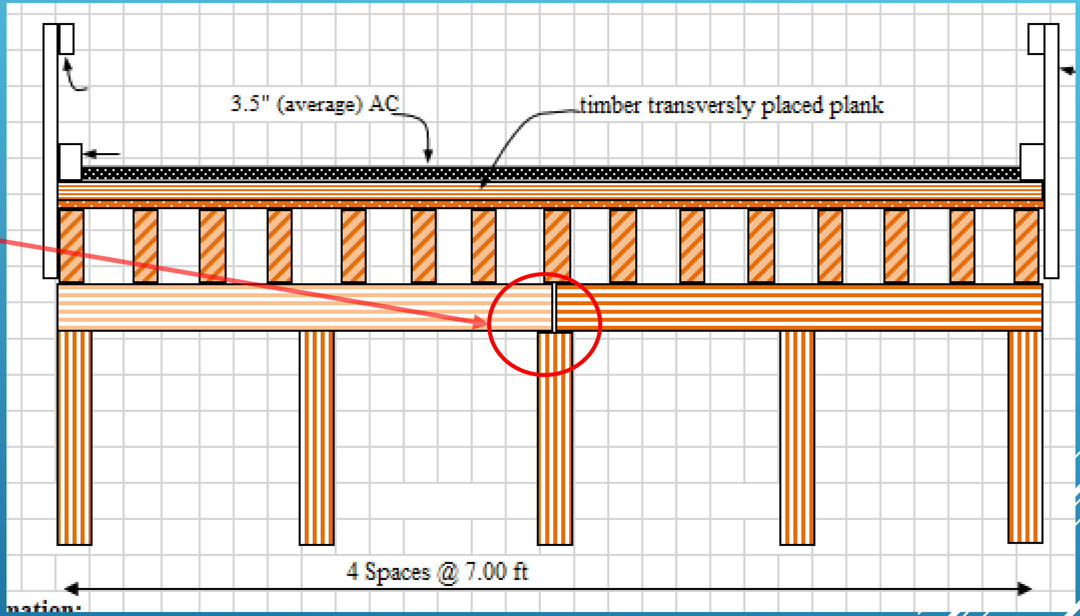
- **BRIEF DETAILS OF THE BRIDGE.**
  - Year Built Date Unknown – approx. 1943
  - **Posted** for 10, 16, and 20 Tons for Type 3, Type 3S2, and Type 3-3 respectively based on Stringer Capacity
  - Inspection Cycle is set at 12 months
  - AC Overlay 3" at edge and 4" at CL of the bridge
  - 2 Simple Spans
  - 15 Stringers
  - Bent Cap (Bent 2) is supported by 5 Timber Piles
  - Recent Inspection showed that **Bent Caps** have 'core rot' and load rating is needed

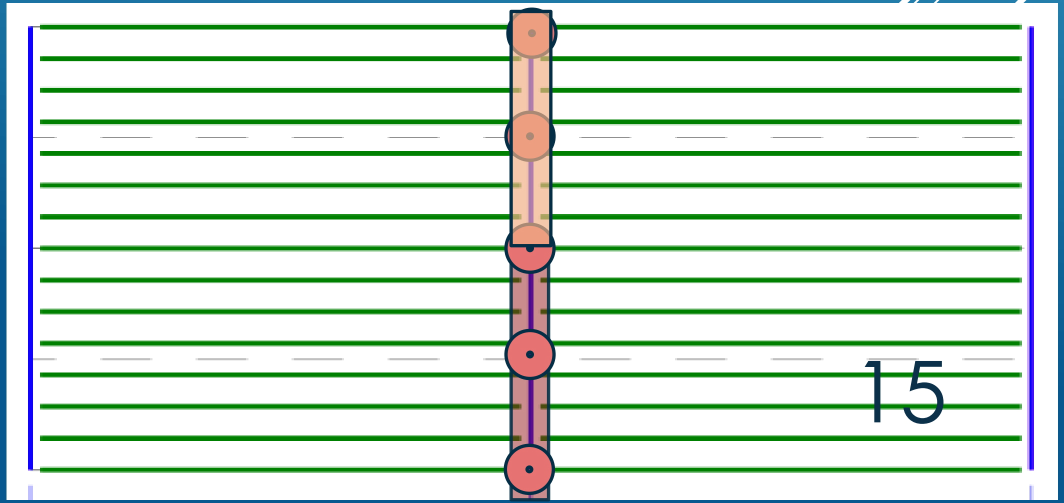


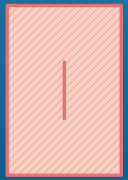


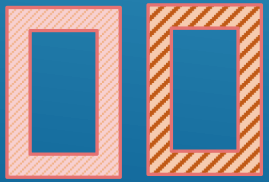
EXAMPLE – TWO SPAN TIMBER BRIDGE

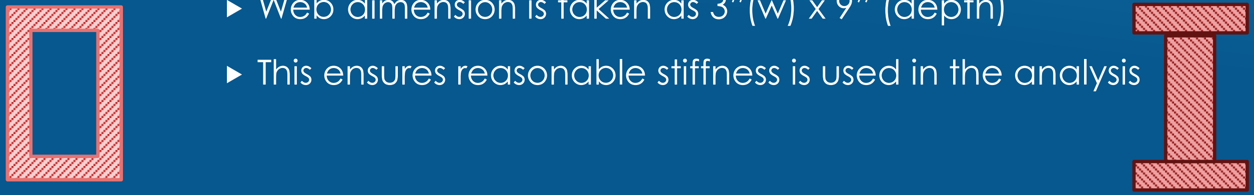
- **BRIEF DETAILS OF THE BRIDGE.**
  - Bent Cap is supporting stringers of Span 1 and Span 2
  - Bent cap beam is discontinuous at Column 3
  - Recent Inspection showed that **Bent Cap** has 'core rot' and load rating is needed
    - Original Size is 12" x 12"
    - 1.5" outside core is intact
    - For Modeling purposes,
      - Top and bottom flange dimension is taken as 12" x 1.5"
      - Web dimension is taken as 3"(w) x 9" (depth)
      - This ensures reasonable stiffness is used in the analysis







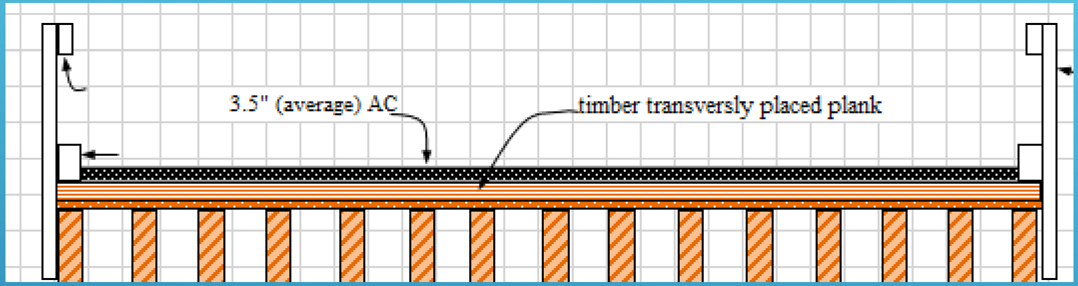


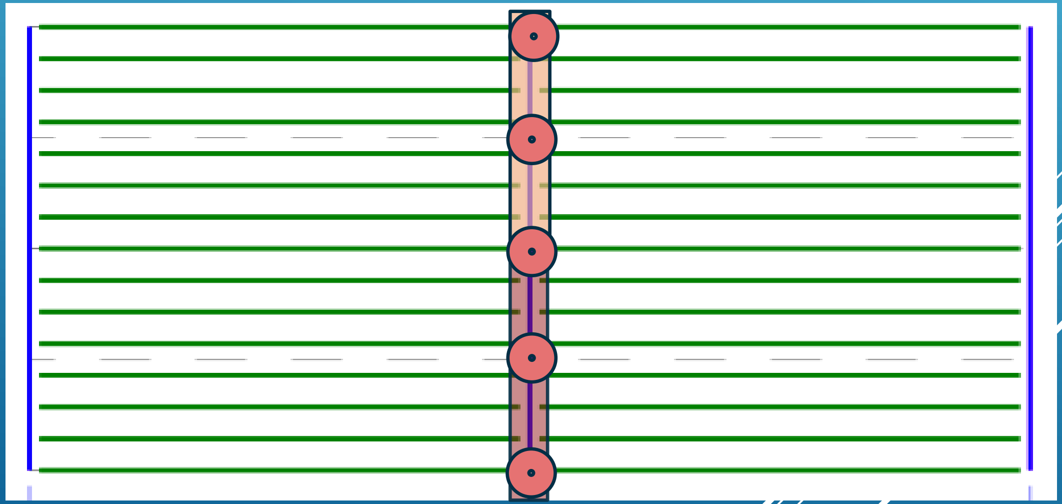


EXAMPLE – TWO SPAN TIMBER BRIDGE

- **Load Rating of Timber Stringers**
  - **Stringers of Span 1 and Span 2 are load rated using BrDR Girder System Approach**

SUPERSTRUCTURE DEFINITIONS
- Span 1 (MDL 1 of 1)
- Span 2 (MDL 1 of 1)





Span 1 (MDL 1 of 1)
- Impact/Dynamic Load Allowance
- Load Case Description
- Framing Plan Detail
- Bracing Deterioration
- BSC Bracing Spec Check Selection
- Deck
- Structure Typical Section
- Superstructure Loads
- MEMBERS
  - G1
  - G2
  - G3 (G2)
  - G4 (G2)
  - G5 (G2)
  - G6 (G2)
  - G7 (G2)
  - G8 (G2)
  - G9 (G2)
  - G10 (G2)
  - G11 (G2)
  - G12 (G2)
  - G13 (G2)
  - G14 (G2)
  - G15 (G1)

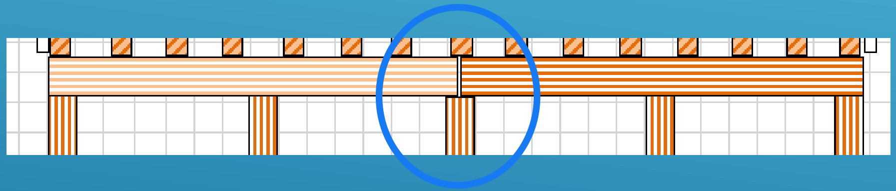
ASR

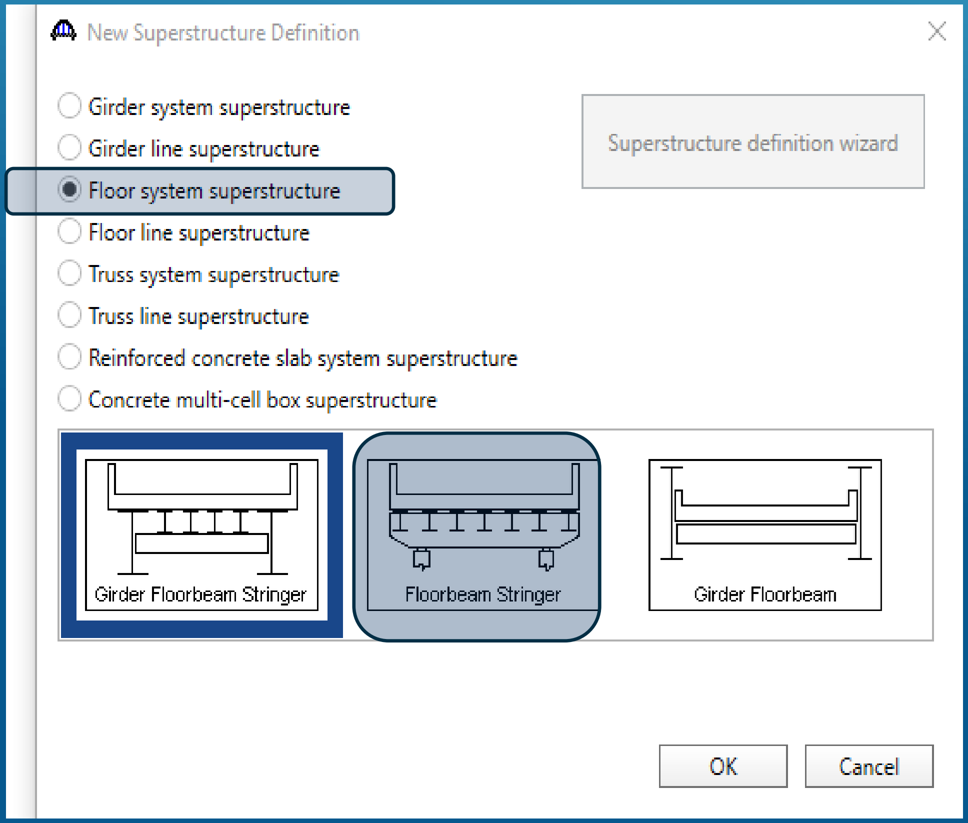
Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)
HS 20-44	Axle Load		Inventory	7.72
HS 20-44	Lane		Inventory	10.54
HS 20-44	Axle Load		Operating	11.93
HS 20-44	Lane	ASD	Operating	16.28
Type 3	Axle Load	ASD	Operating	10.19
Type 3-3	Axle Load	ASD	Operating	19.80
Type 3S2	Axle Load	ASD	Operating	16.10

LRFR

Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)
HL-93 (US)	Truck + L		Inventory	8.25
HL-93 (US)	Tandem + L		Inventory	7.07
HL-93 (US)	Truck + L		Operating	10.69
HL-93 (US)	Tandem + Lane	LRFR	Operating	9.16
Lane-Type Legal Load	Truck + Lane	LRFR	Legal	3960.00
Type 3	Axle Load	LRFR	Legal	9.95
Type 3-3	Axle Load	LRFR	Legal	19.34
Type 3S2	Axle Load	LRFR	Legal	15.72

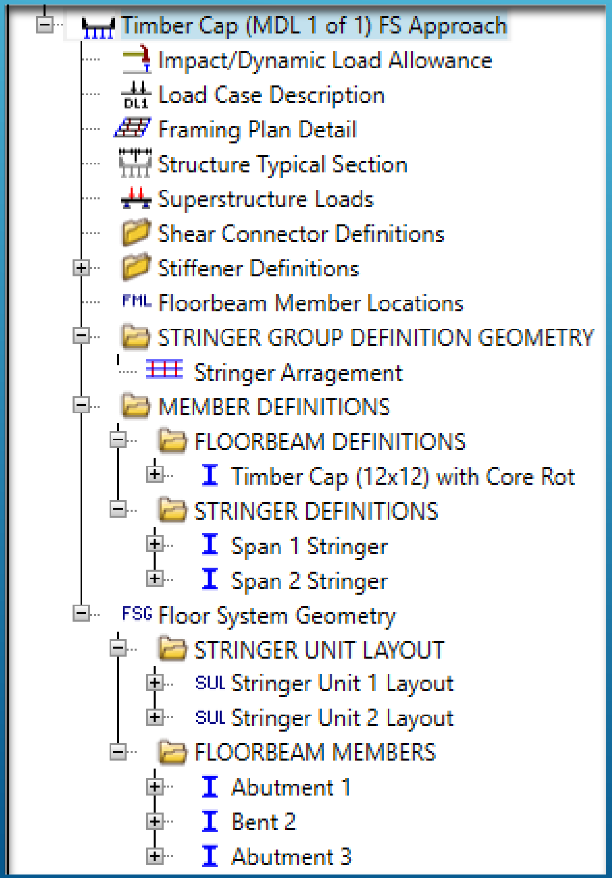
EXAMPLE – TWO SPAN TIMBER BRIDGE





- Cap is cut into two pieces, so It will be treated as **a hinge**
- Only (**F**B **S**tringer) **FS** can accept **hinge** when the floor beam FS is chosen

SELECTION OF FLOOR SYSTEM SUPERSTRUCTURE

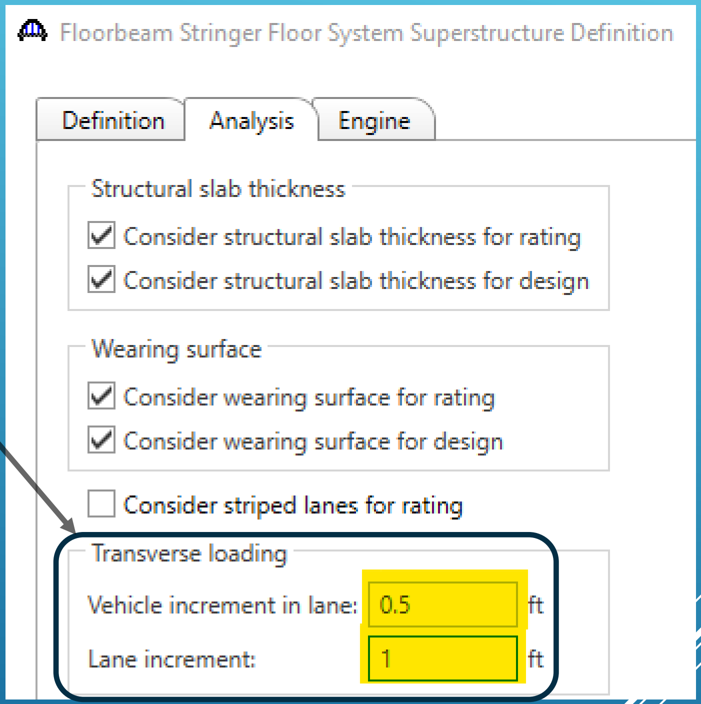


- Once the software creates the entire tree, the User needs to enter appropriate data within each GUI.
- A few important data entries are discussed next.

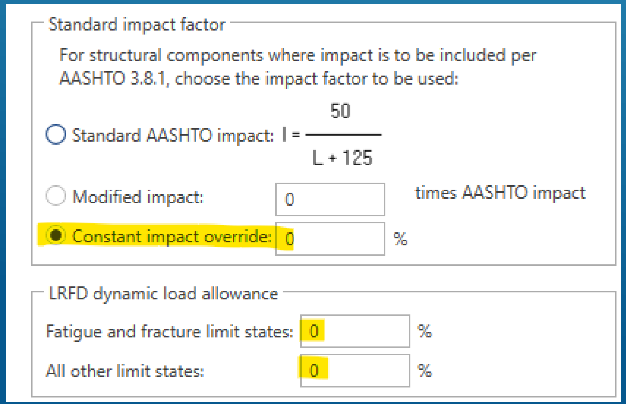
CREATE A FS MODEL

CREATE A FS MODEL

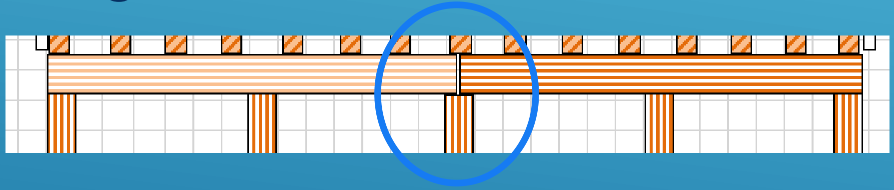
- **Analysis Tab** of Floor System Superstructure Definition
  - Vehicle increment in Lane and Lane Increment for transverse loading need adjustments
  - Default values of 2 ft and 4 ft are too large for a Timber bridge where stringers are spaced less than 2 ft.
    - If axles are moved greater than stringer spacing, loads demands will not correctly be established
    - But, Analysis time will increase with a smaller increment

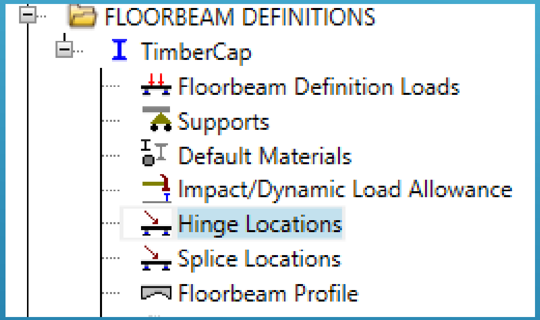


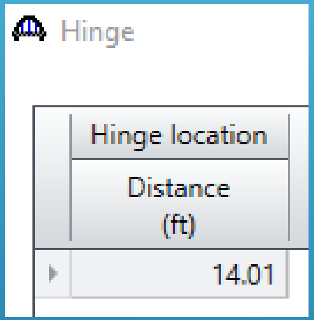
- **Impact/DLA to be 0.0**
  - Std Spec. Article 3.8.1
  - LRFD Article 3.6.2.3



- **Hinge Location**

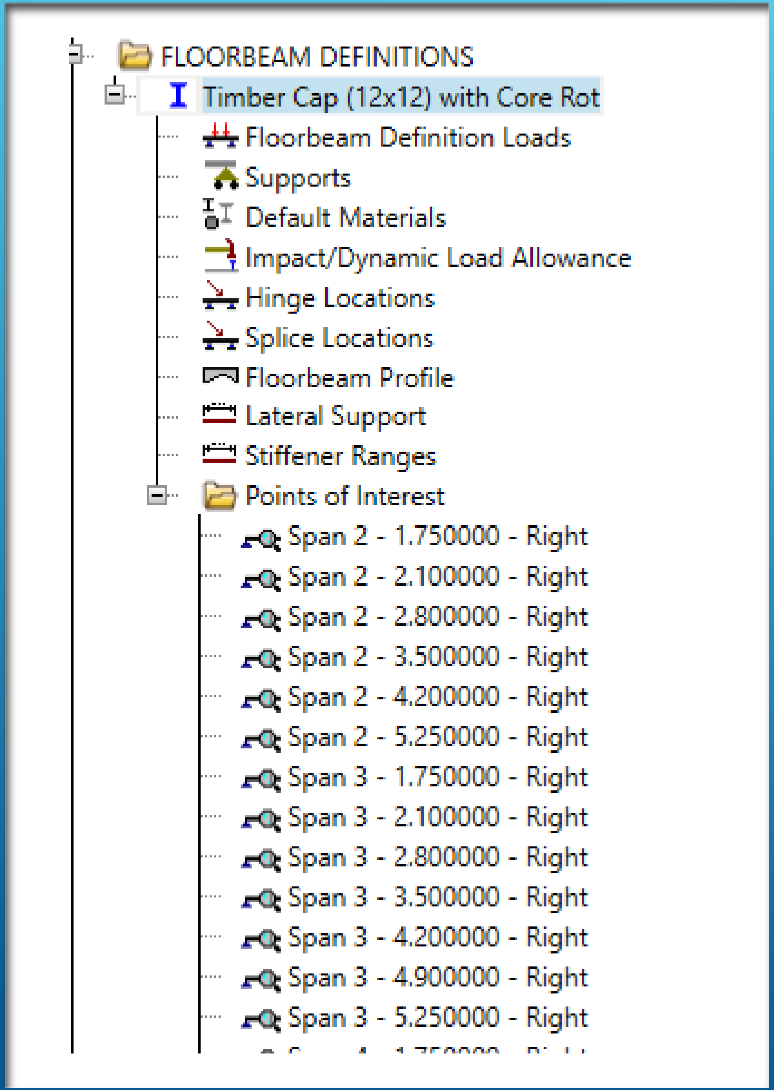


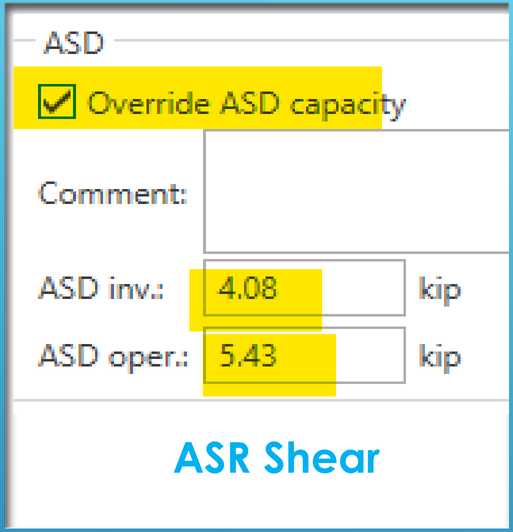


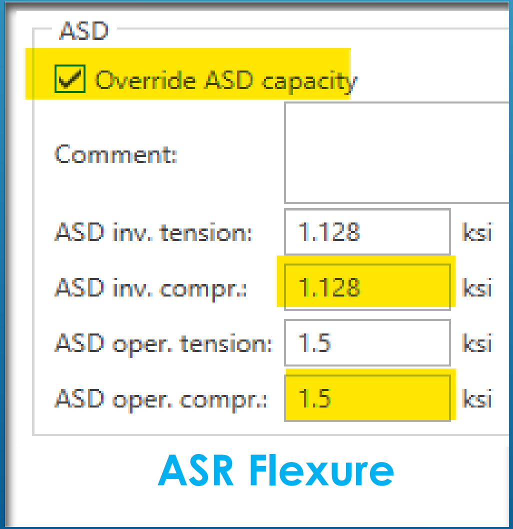


CREATE A FS MODEL

- Point of Interest Within Floor Beam Definitions (For ASR)
  - All 10th points
  - Critical Shear Location
  - Overwrite the Capacity.
    - Typically, flexural capacity will be the same at ALL points
    - shear capacity needs not to be done within "d" distance from the support. Enter a larger capacity so that shear analysis will NOT control







CREATE A FS MODEL

- **Point of Interest Within Floor Beam Definitions (For LRFR)**
  - All 10th points
  - Critical Shear Location
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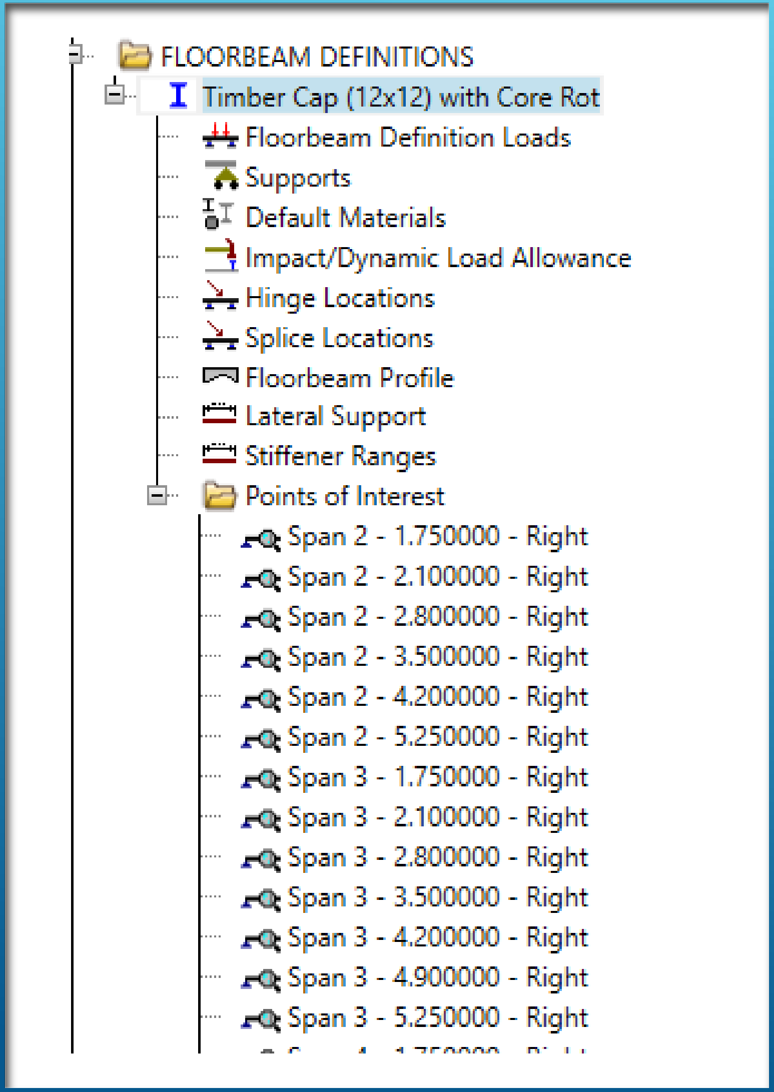
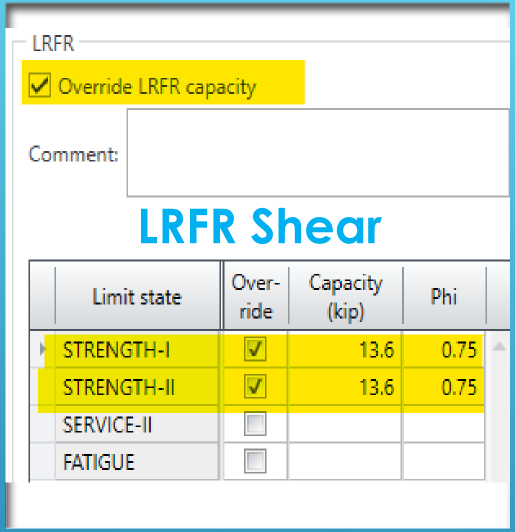
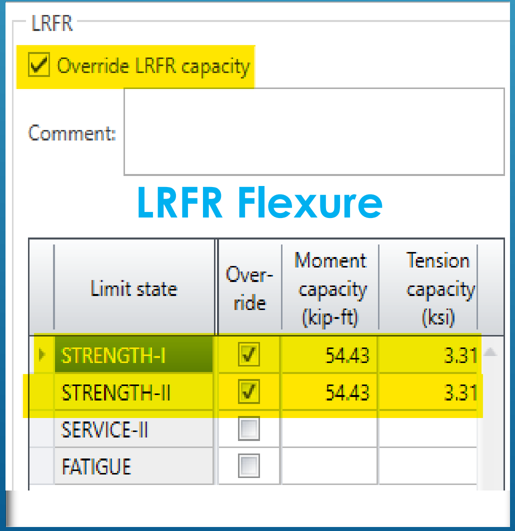






CREATE A FS MODEL

ANALYSIS RESULTS

➢ CAP Rating Results

ASR

Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)
HS 20-44	Axle Load		Inventory	2.85
HS 20-44	Axle Load		Operating	6.11
HS 20-44	Lane	ASD	Inventory	3.02
HS 20-44	Lane	ASD	Operating	6.47
Type 3	Axle Load	ASD	Operating	5.19
Type 3-3	Axle Load	ASD	Operating	10.33
Type 3S2	Axle Load	ASD	Operating	7.72

LRFR

Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)
HL-93 (US)	Truck + Lane		Inventory	5.56
HL-93 (US)	Truck + Lane		Operating	7.21
HL-93 (US)	Tandem + Lane	LRFR	Inventory	5.05
HL-93 (US)	Tandem + Lane	LRFR	Operating	6.55
Lane-Type Legal Load	Truck + Lane	LRFR	Legal	3960.00
Type 3	Axle Load	LRFR	Legal	7.31
Type 3-3	Axle Load	LRFR	Legal	14.53
Type 3S2	Axle Load	LRFR	Legal	10.86

When placing the wheels on Cap directly, ASR load rating produces 3, 3, 5 Tons for Type 3, 3S2, and 3-3 respectively. Bridge is currently posted for 3, 3, 5 Tons.

➢ Support/Column Reactions

Analysis Results - Bent 2 Cap

Print

Print

Report type: Live Load Actions

Stage: Composite (short term) (Stage 3)

Live Load: HS 20-44

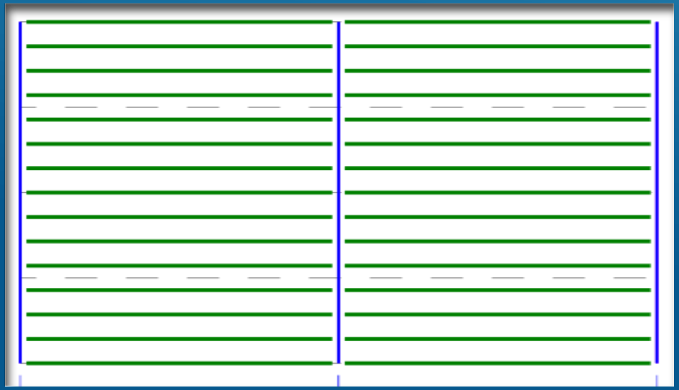
Live Load Type: Axle Load

Span	Location (ft)	% Span	Positive Moment (kip-ft)	Negative Moment (kip-ft)	Positive Shear (kip)	Negative Shear (kip)	Positive Axial (kip)	Negative Axial (kip)	Positive Reaction (kip)	Negative Reaction (kip)
1	0.00	0.0	0.00	0.00	11.56	-1.87	0.00	0.00	11.56	-1.87

Support	HS20	Type 3	Type 3S2	Type 3-3
Column 1	11.56	9.44	9.14	7.59
Column 2	29.84	24.35	23.59	19.59
Column 3	25.84	21.09	20.43	16.97
Column 4	29.82	24.34	23.58	19.58
Column 5	11.56	9.44	9.14	7.59

CONCLUDING REMARKS

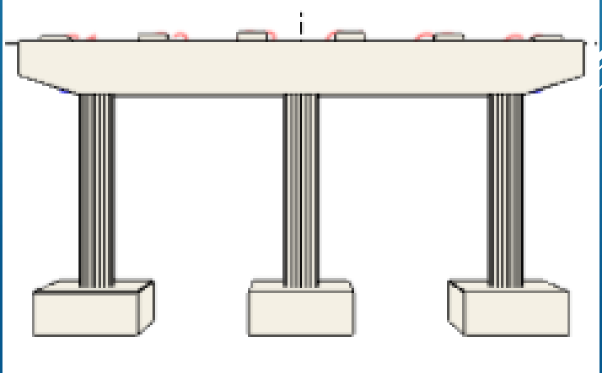
- No workaround is needed to load Steel Bent Cap, except treating the Floor beam as Cap.
- This workaround will work for Timber Floor Beams
  - Steel Truss bridges with Timber deck / Stringer / Floor beam System
  - Suspension bridges with Timber Deck



- Limitations of this workaround
  1. Number of Stringers in both spans must be the same (BrDR Limitation)
  2. Capacity needs to be established outside of the BrDR software
     - A girder line model within the BrDR can be used to establish Capacity

CONCLUDING REMARKS

- **Possible Enhancements**
  - Modify the software so that GFS and FS floor systems accept "Timber" stringers and Floor beams
  - Allow different number of Girders in each Structural Unit
  - Modify the Substructure Module so that it analyzes Timber Caps



1. DETAILED STEP BY STEP MODELING PROCESS
(SLIDES 34 THROUGH 71)
2. ESTABLISHING CAP CAPACITY USING BRDR SOFTWARE
(SLIDES 72 THROUGH 76)

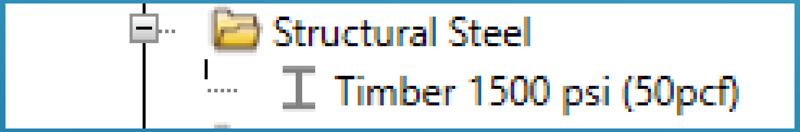
ANY QUESTIONS?

THANK YOU!

STEP BY STEP MODELING PROCESS

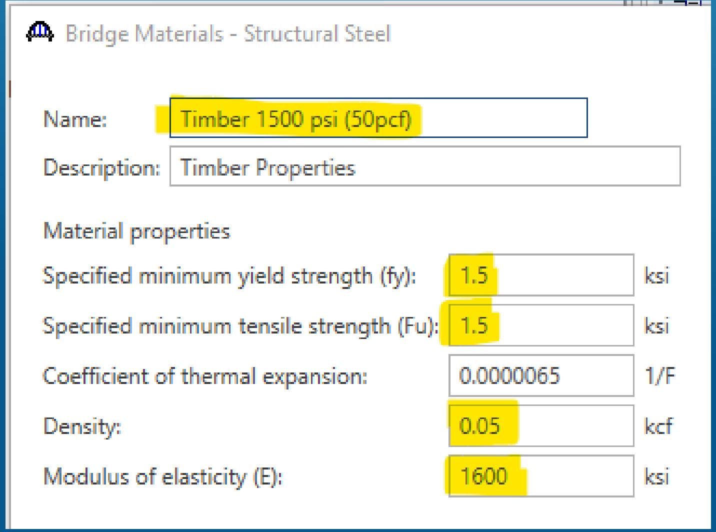
MODELING THE CAP

- 1. Generate "User Defined" Material Properties
  - 1.1 Steel Girder Material is changed to match the Timber material properties.



The allowable stress of the Timber Cap can be left as it.

However, It is recommended to enter the "inventory" allowable stress of the timber material

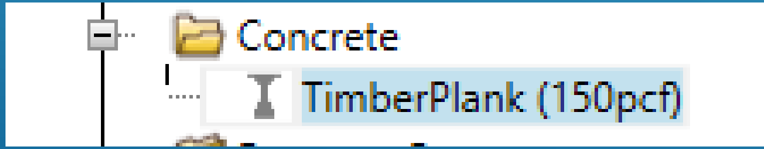


MODELING THE TIMBER CAP

- 1. Generate "User Defined" Material Properties (Cont'd)
  - 1.2 Create Concrete Material to handle Timber planks

The software will NOT allow the user to enter 50 pcf density concrete

As a result, a concrete deck with 150 pcf density concrete will be generated. The deck thickness will be adjusted to handle the difference in weight.

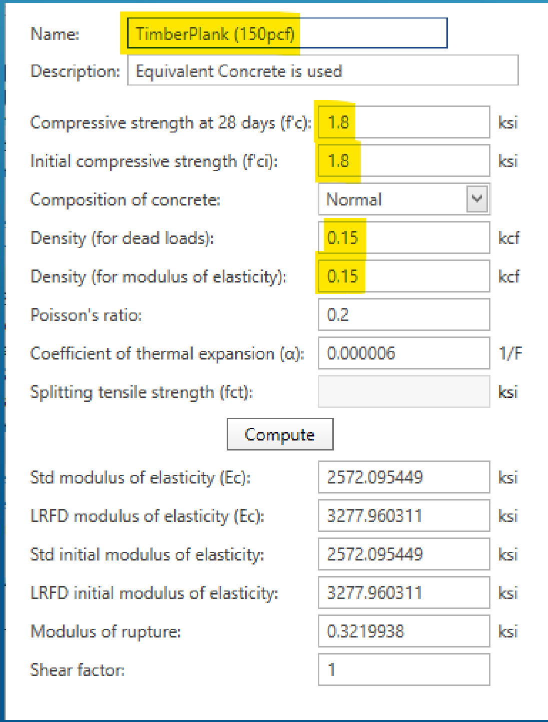


NOTE: Deck is used to establish the dead weight of the spans only.

Be sure to change the Name to reflect the properties used.

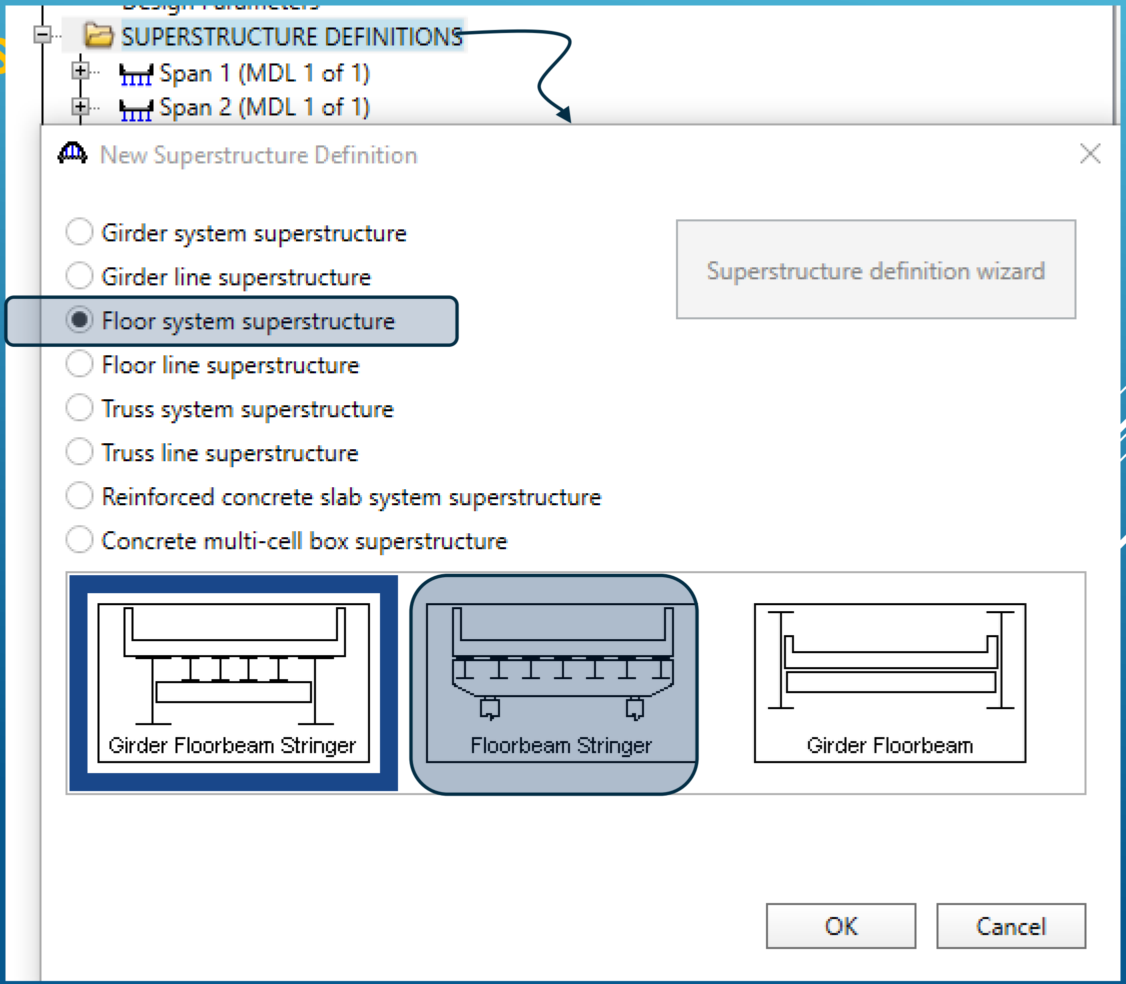
Since we are only interested in density, name is set as

TimberPlank (150 pcf)



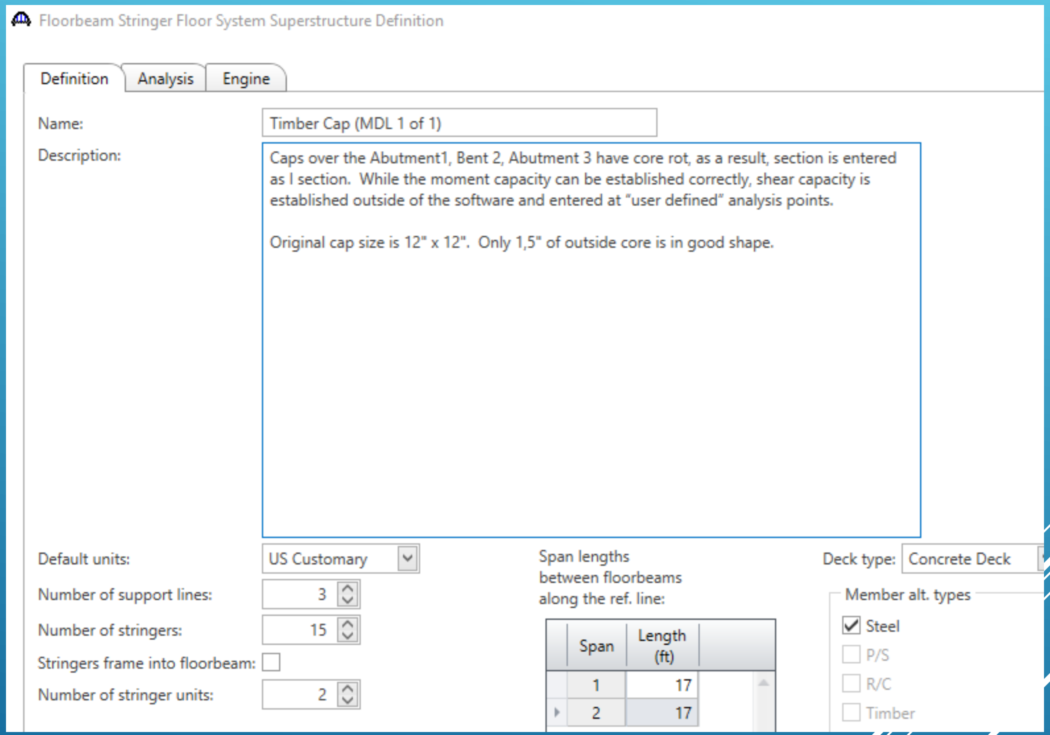
MODELING THE TIMBER CAP

- 2. Create a **FS Model**
  - Double click on **SUPERSTRUCTURE DEFINTIONS**
  - Choose **Floor system superstructure**
  - Select **Floorbeam Stringer** (FS) Picture
  - Click OK



MODELING THE TIMBER CAP

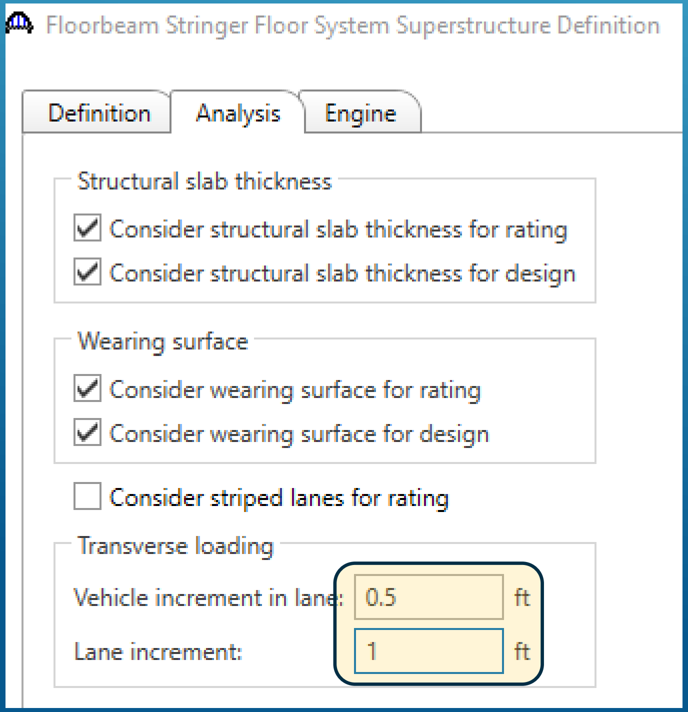
- 2.1 Create an **FS Model** *Cont'd*
  1. Name = **Timber Cap (MDL 1 of 1)**
  2. Deck Type = **Concrete Deck**
  3. Member Alt Types = **Steel**
  4. Number of support line = **3**
  5. Number of Stringers = **15**
  6. Stringers frame into floorbeam = **NO** (uncheck)
  7. Number of Stringer units = **2**
  8. Span Lengths = **17**ft, **17**ft
  9. Description =

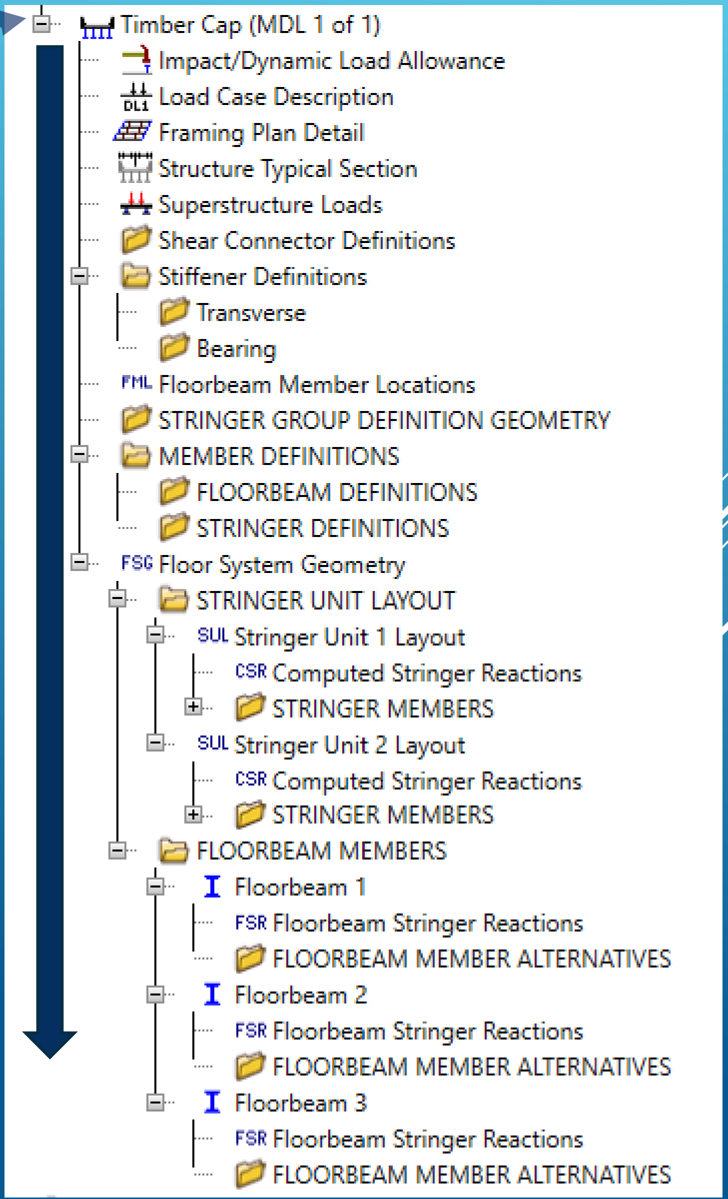


Note: Once the user clicks the OK button, most of the selection cannot be modified

MODELING THE TIMBER CAP

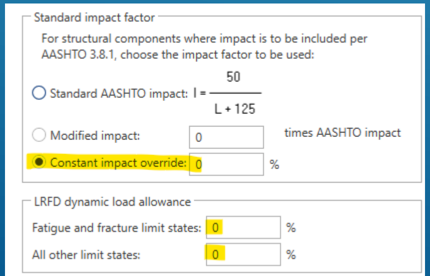
- 2.1 Create an **FS Model** <u>Cont'd</u>
  - 2.1.0 Analysis Tab





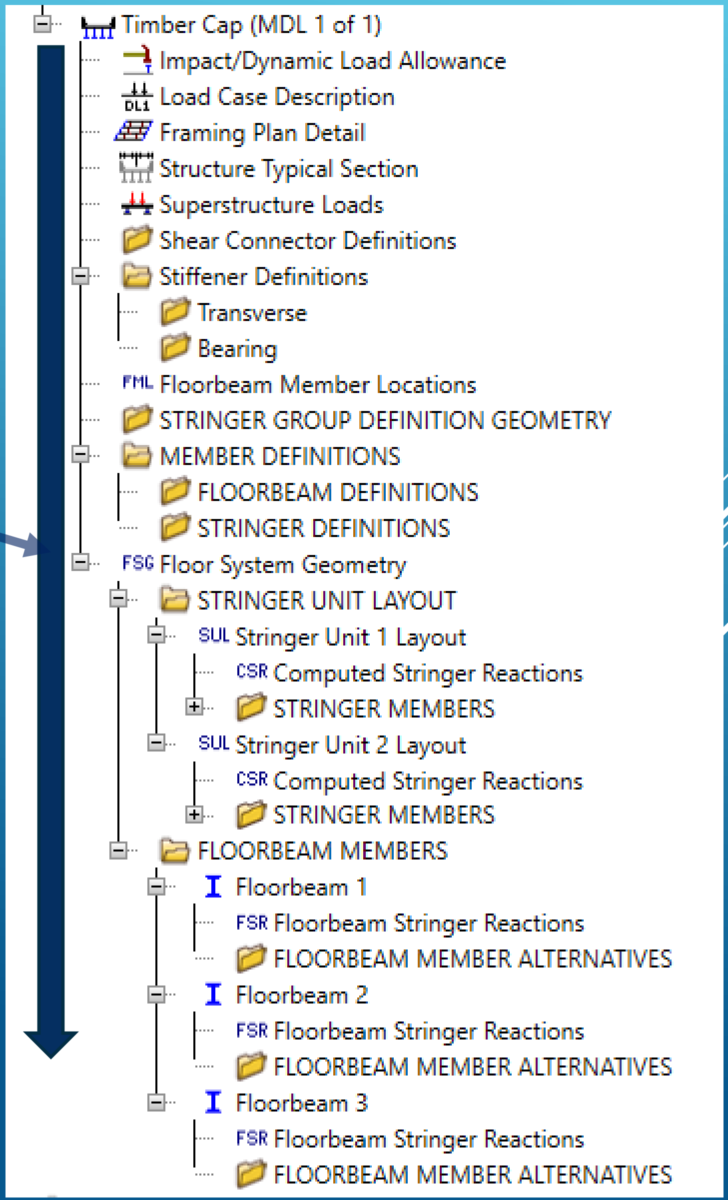
MODELING THE TIMBER CAP

- 2.1 Create an **FS Model** Cont'd
  - BrDR tree for GFS is shown here. The user needs to enter data from top to bottom.
  - 2.1.1 Impact/DLA



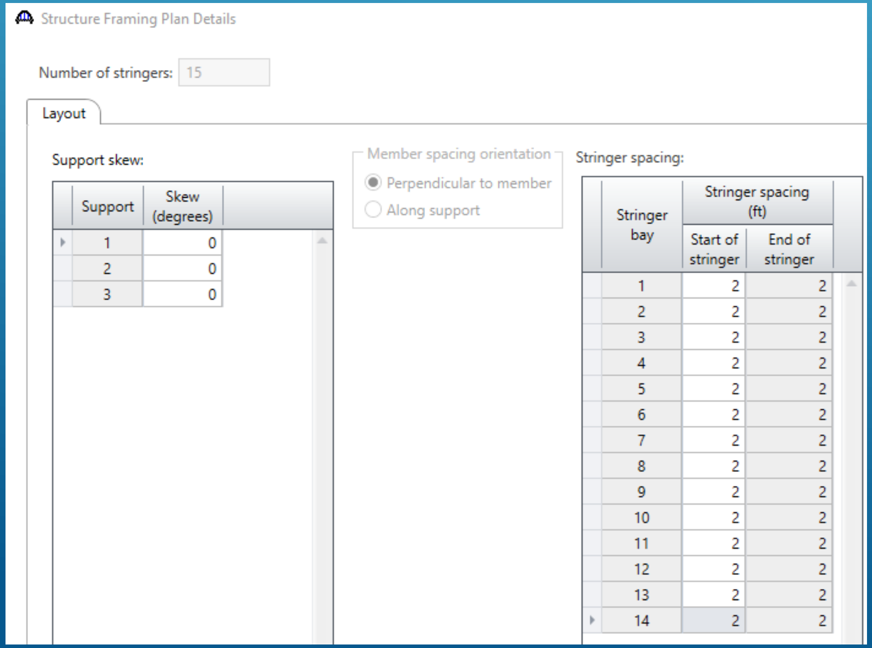
  - 2.1.2 Load Case Description

Load case name	Description	Stage	Type
DC1	DC acting on non-composite section	Non-composite (Stage 1)	D,DC
DC2	DC acting on long-term composite section	Composite (long term) (Stage 2)	D,DC
DW	DW acting on long-term composite section	Composite (long term) (Stage 2)	D,DW

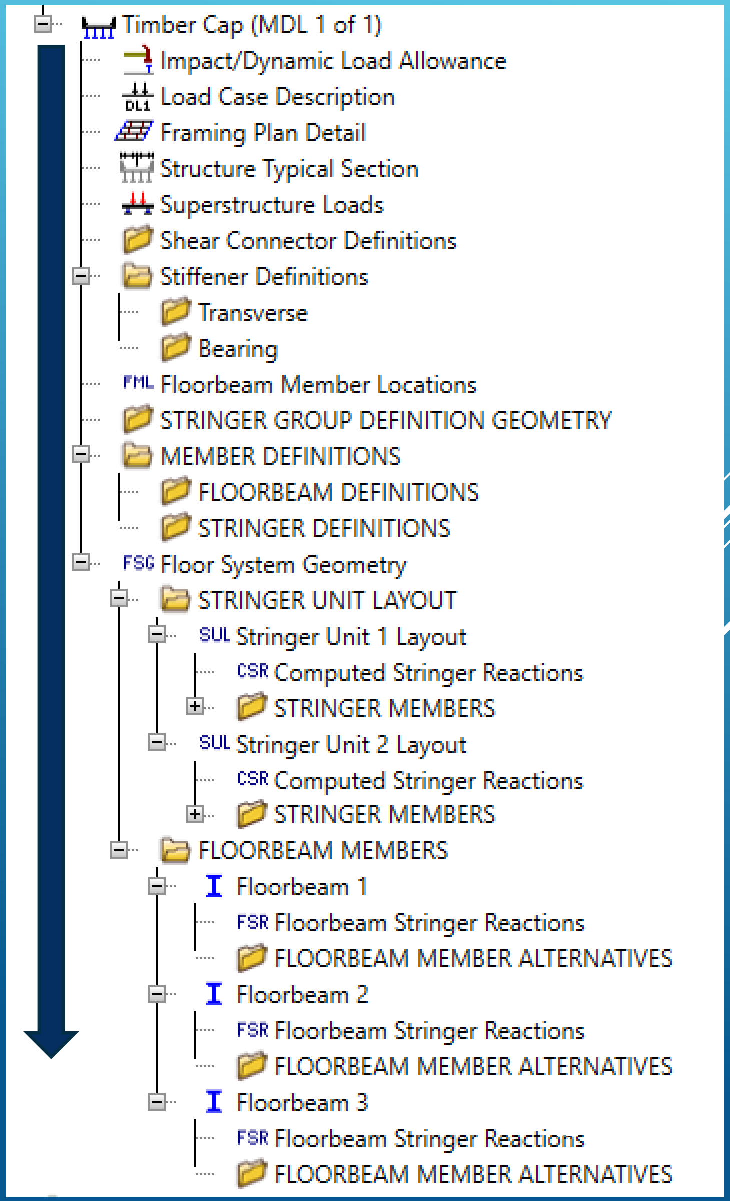


MODELING THE TIMBER CAP

- 2.1 Create an **FS Model** Cont'd
  - 2.1.3 Framing Plan Details

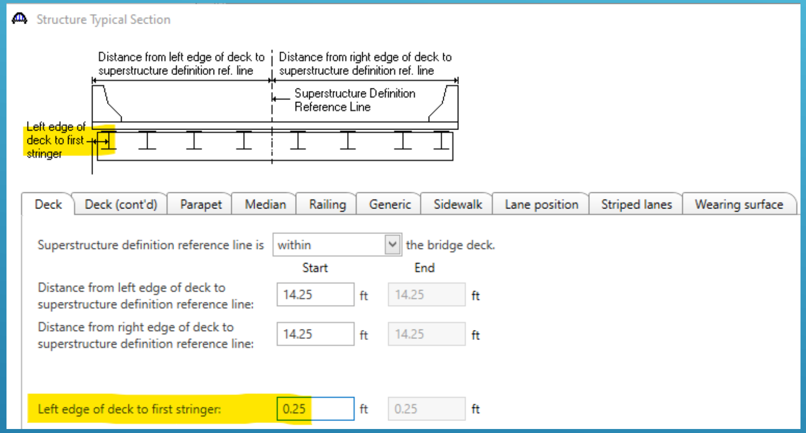


  - Stringers have to be parallel to each other.

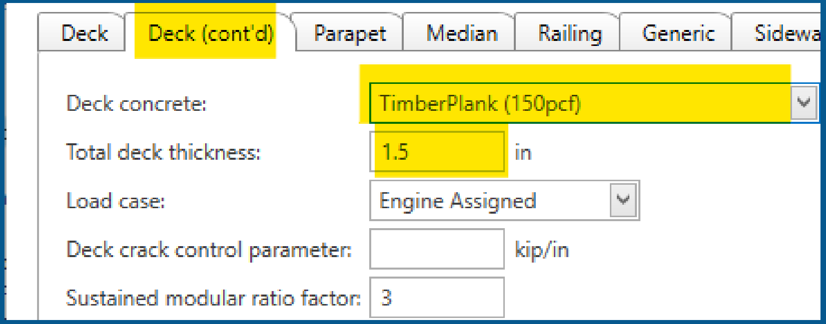


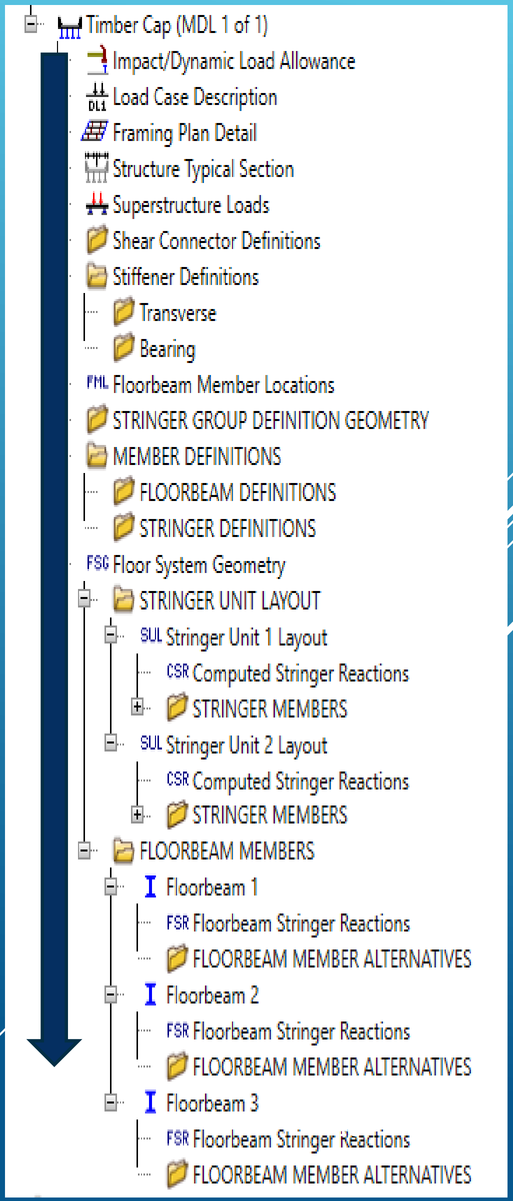
MODELING THE TIMBER CAP

- 2.1 Create a **FS Model** Cont'd
  - 2.1.4 Structure Typical Section



    - Locate first stringer relative to edge of deck
  - 2.1.4.1 Deck
    - Equivalent concrete deck for 4.5" Timber deck
    - = 4.5" x 50pcf /150pcf = 1.5 inches
    - Select "user defined" equivalent Deck Concrete





MODELING THE TIMBER CAP

- 2.1 Create a **FS Model** Cont'd
  - 2.1.4 Structure Typical Section, Cont'd
  - 2.1.4.2 Barrier (Generic)

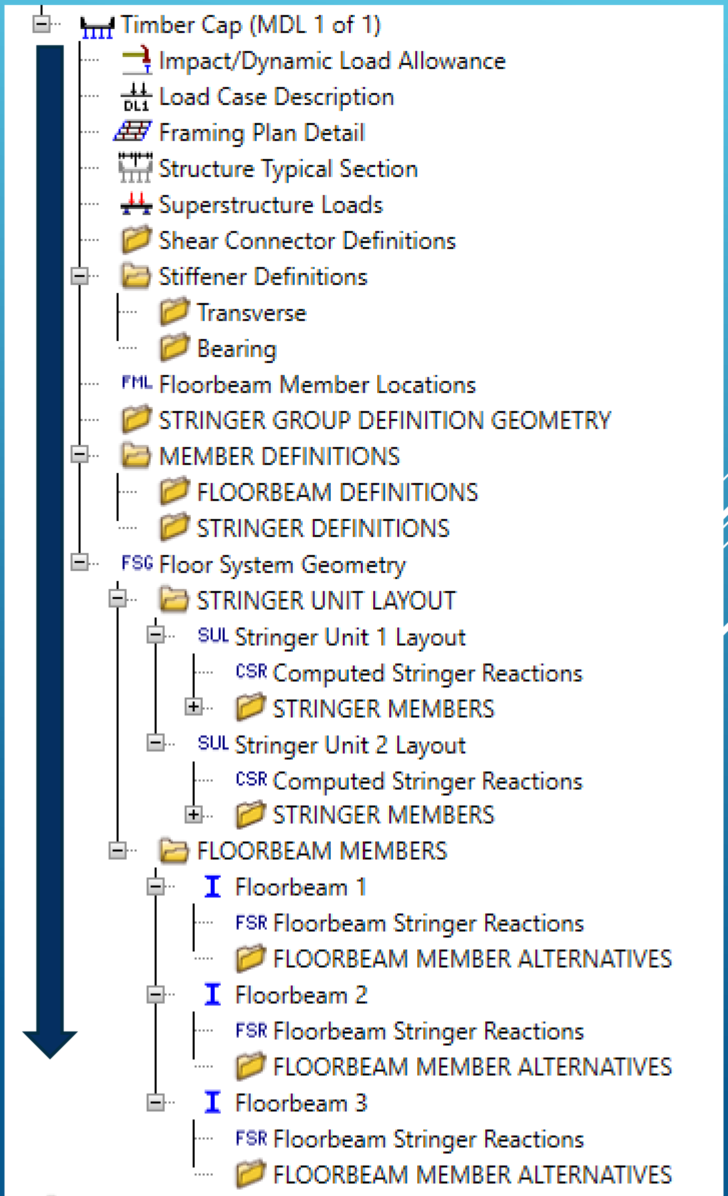
Deck | Deck (cont'd) | Parapet | Median | Railing | Generic | Sidewalk | Lane position | Striped lanes | Wearing surface

Name	Load case	Measure to	Edge of deck dist. measured from	Distance at start (ft)	Distance at end (ft)	Front face orientation
MBGR (Sgl Rail,WD 6x8 POST)	DC2	Front	Left Edge	0.25	0.25	Right
MBGR (Sgl Rail,WD 6x8 POST)	DC2	Front	Right Edge	0.25	0.25	Left

  - 2.1.4.3 Lane Position

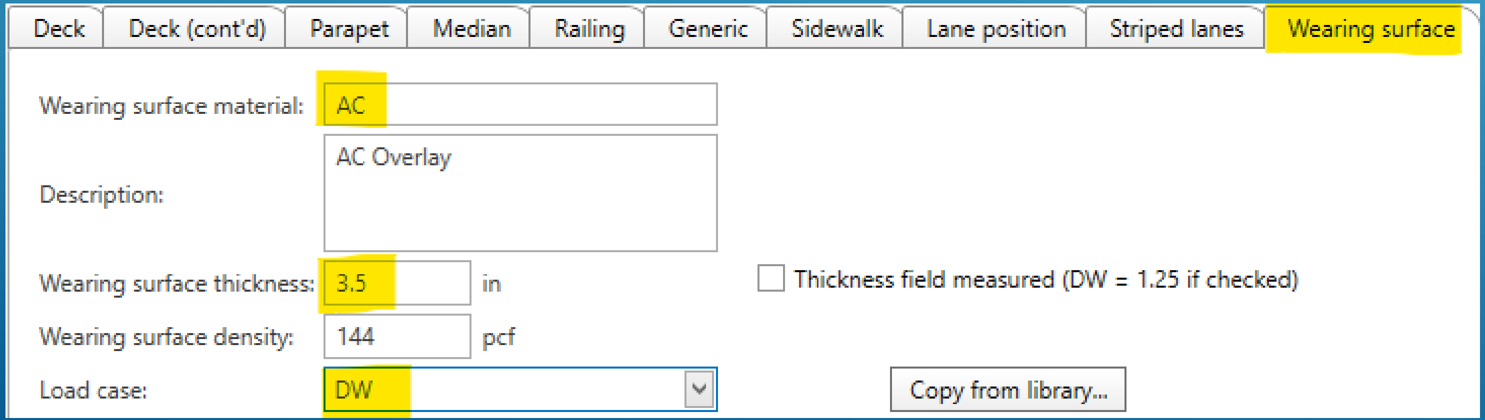
Deck | Deck (cont'd) | Parapet | Median | Railing | Generic | Sidewalk | Lane position | Striped lanes | Wearing surface

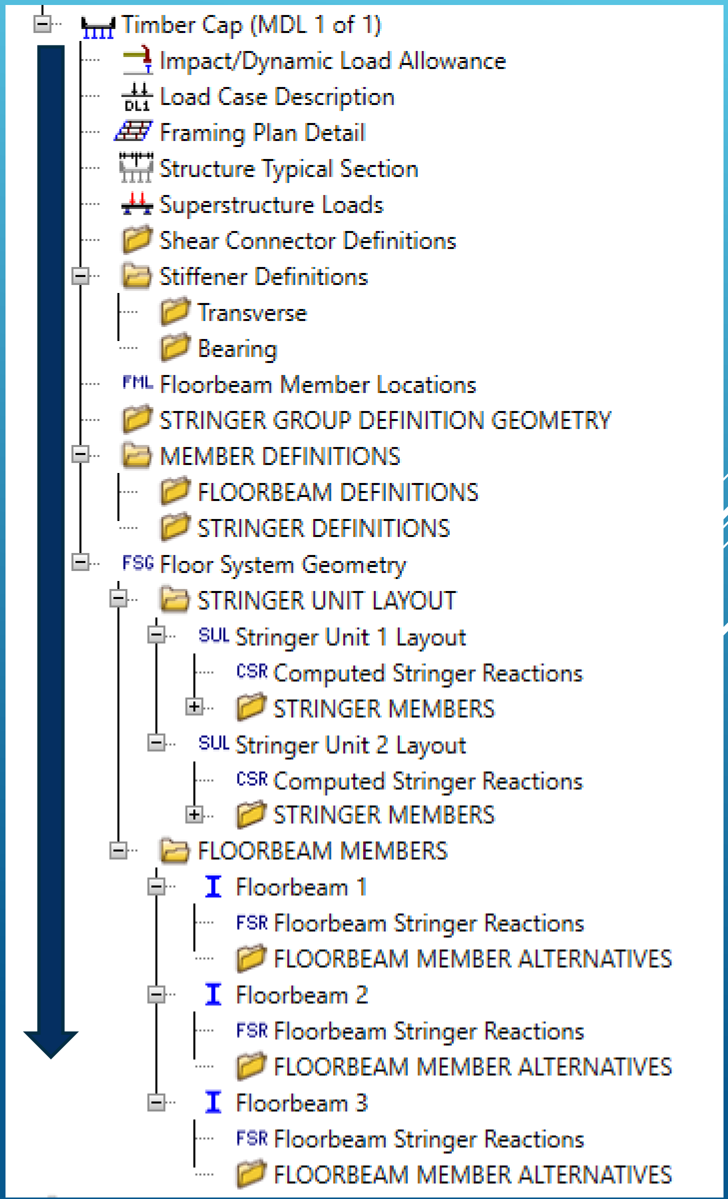
Travelway number	Distance from left edge of travelway to superstructure definition reference line at start (A) (ft)	Distance from right edge of travelway to superstructure definition reference line at start (B) (ft)	Distance from left edge of travelway to superstructure definition reference line at end (A) (ft)	Distance from right edge of travelway to superstructure definition reference line at end (B) (ft)
1	-14	14	-14	14



MODELING THE TIMBER CAP

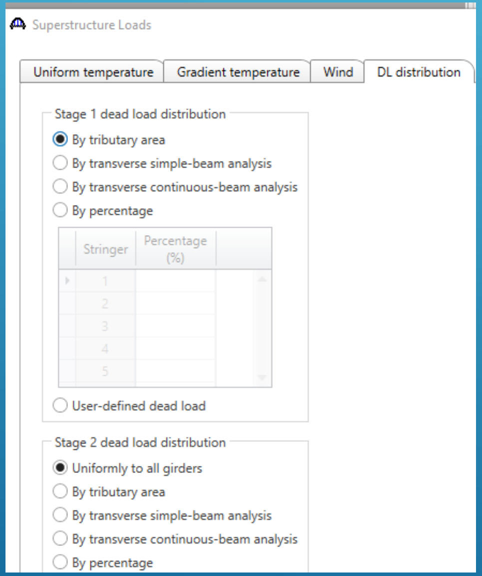
- 2.1 Create a **FS Model** Cont'd
  - 2.1.4 Structure Typical Section, Cont'd
  - 2.1.4.3 Wearing Surface

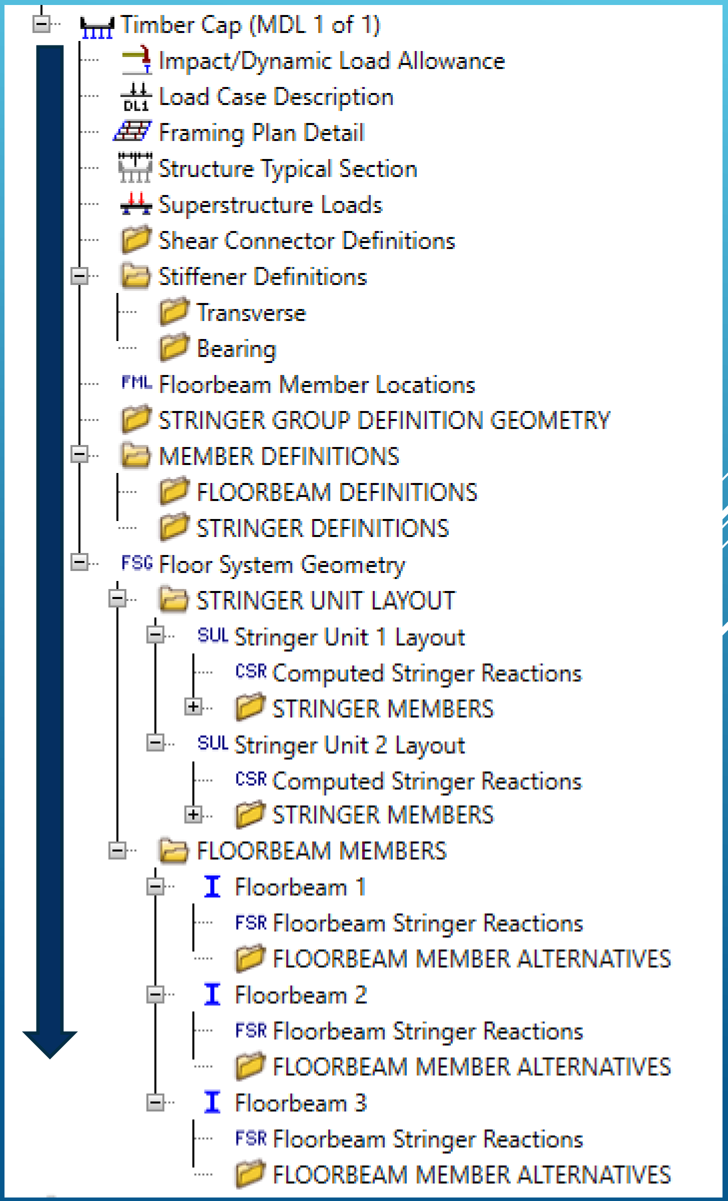




MODELING THE TIMBER CAP

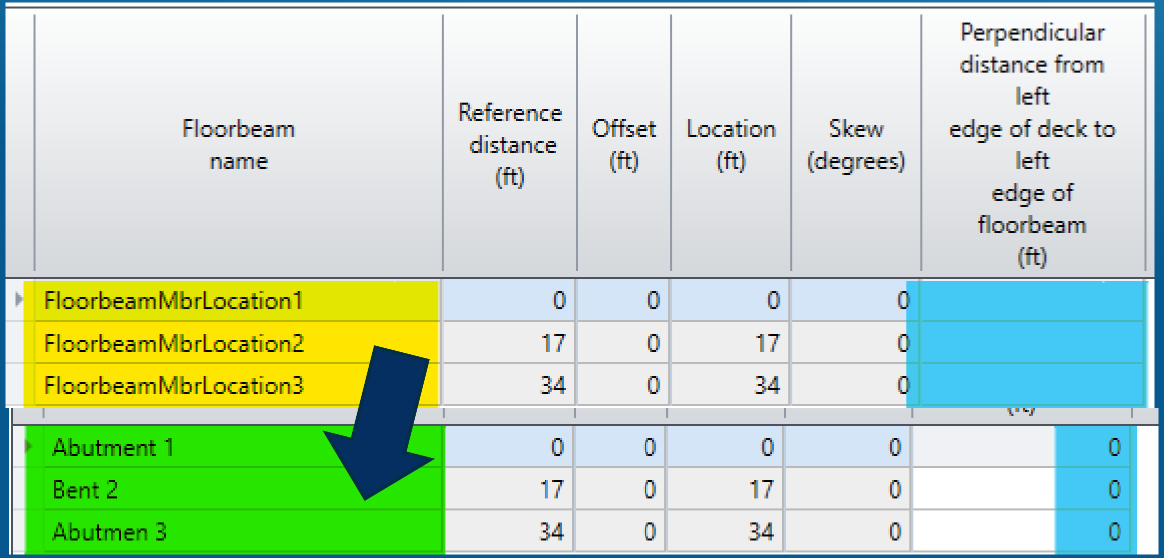
- 2.1 Create a **FS Model** Cont'd
  - 2.1.5 Superstructure Loads
    - No temperature and wind loads
    - DL distribution – use to the default settings
  - 2.16 Shear Connector definition
    - Since deck, stringers, and caps are timber elements there is no need to define these
  - 2.1.7 Stiffener Definition
    - Since capacities will be overwritten at user-defined pt of interests, there is not to define any stiffeners





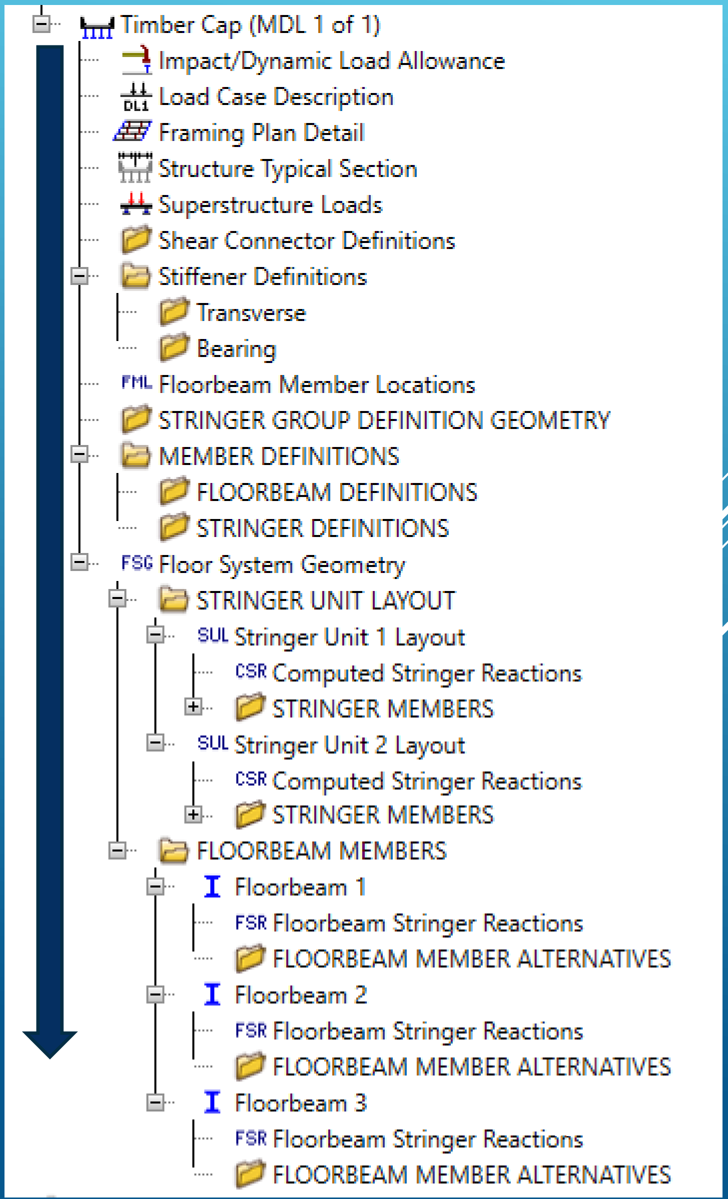
MODELING THE TIMBER CAP

- 2.1 Create an **FS Model** Cont'd
  - 2.1.8 Floorbeam Member Locations
    - Software fills in most of the information needed, however, the user needs to modify it to match the as-built plans.
    - Make sure the Perpendicular distance from the left edge of the deck to the left edge of the floorbeam is correctly entered.
    - Open the GUI and Rename the software defined name to match actual support names.



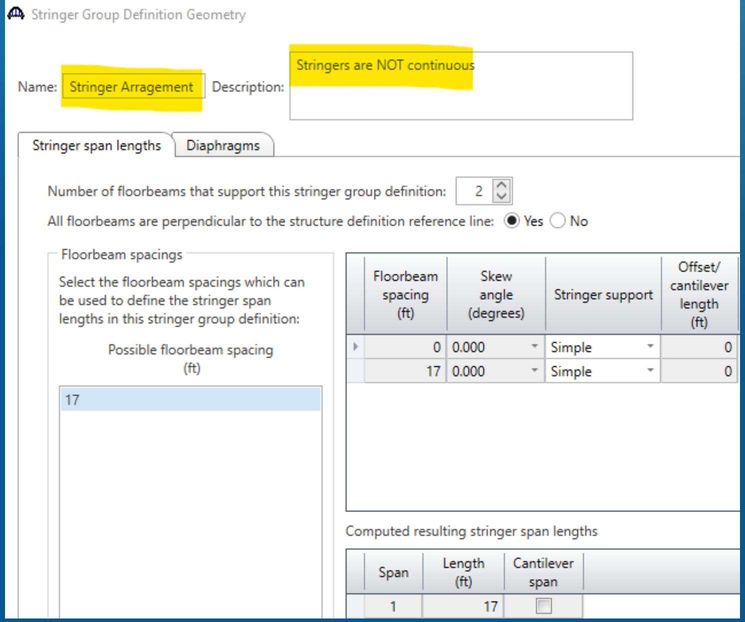
Floorbeam name	Reference distance (ft)	Offset (ft)	Location (ft)	Skew (degrees)	Perpendicular distance from left edge of deck to left edge of floorbeam (ft)
FloorbeamMbrLocation1	0	0	0	0	
FloorbeamMbrLocation2	17	0	17	0	
FloorbeamMbrLocation3	34	0	34	0	

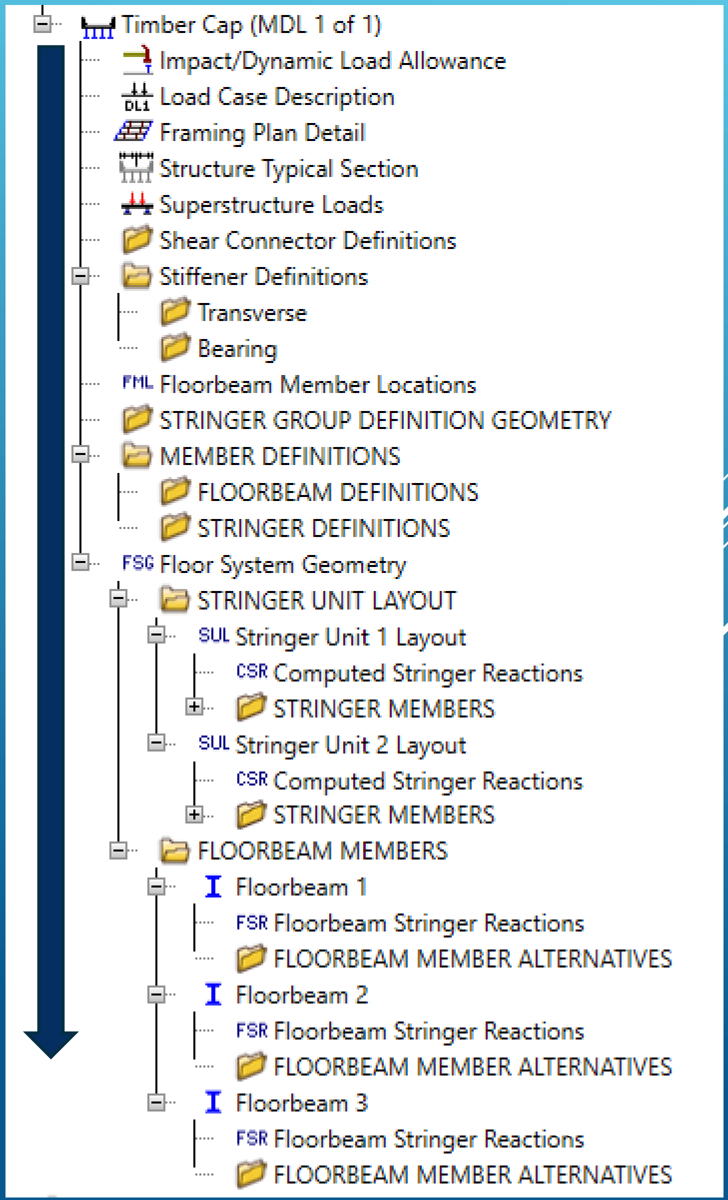
Floorbeam name	Reference distance (ft)	Offset (ft)	Location (ft)	Skew (degrees)	Perpendicular distance from left edge of deck to left edge of floorbeam (ft)
Abutment 1	0	0	0	0	0
Bent 2	17	0	17	0	0
Abutmen 3	34	0	34	0	0



MODELING THE TIMBER CAP

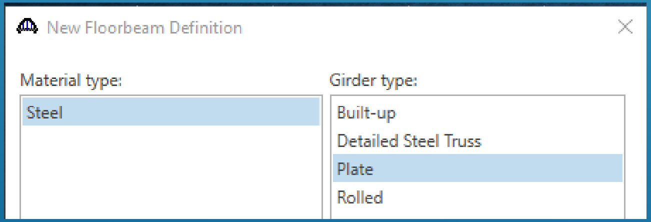
- 2.1 Create an **FS Model** Cont'd
  - 2.1.9 STRINGER GROUP DEFINITION GEOMETRY
    - Software fills in most of the information needed, however, the user needs to verify and adjust them if needed.
    - Typically, timber stringers are simply supported at bents, so "Stringer support" will be simple.
    - Name is assigned as **Stringer Arrangement**



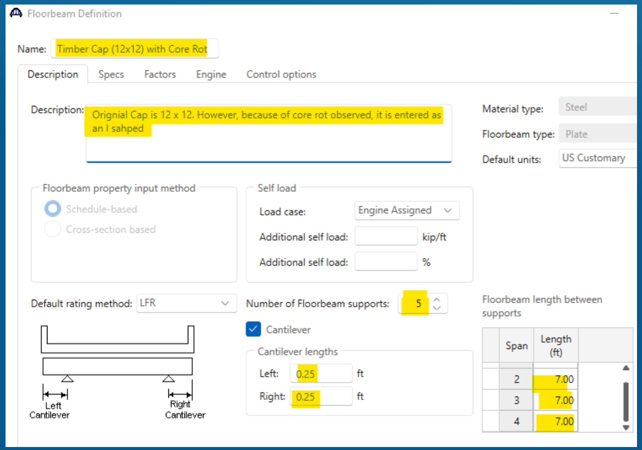


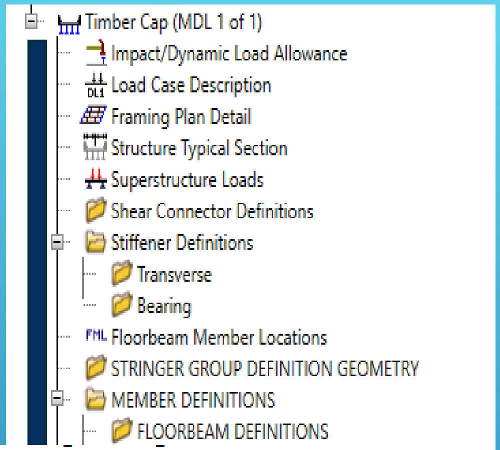
MODELING THE TIMBER CAP

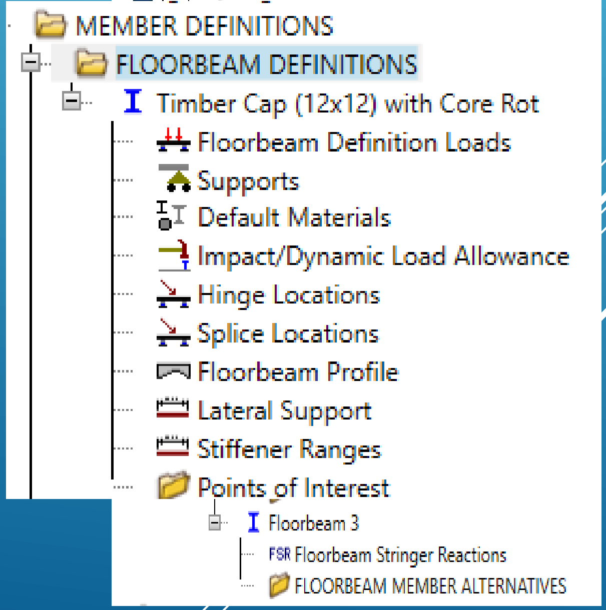
- 2.1 Create a **FS Model** Cont'd
  - 2.1.10 FLOORBEAM DEFINITIONS
    - Note: For this bridge Floorbeam is "Abutment / Bent Cap"
    - Create NEW Floorbeam (rightmouse & new)



- Floor beam is supported by 5 columns and spacing between the supports are: 7ft, 7ft, 7ft, and 7ft
- Floor beam is extended 6" beyond the CL of column support (Cantilevered)
- Name: Timber Cap (12x12)with Cor Rot

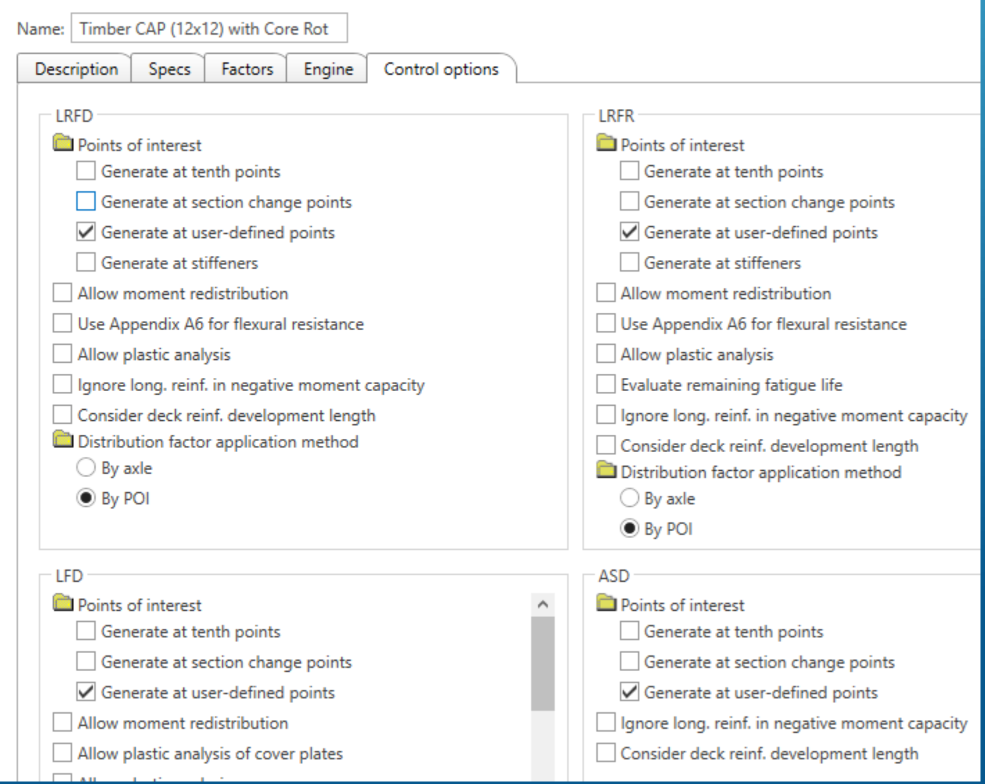


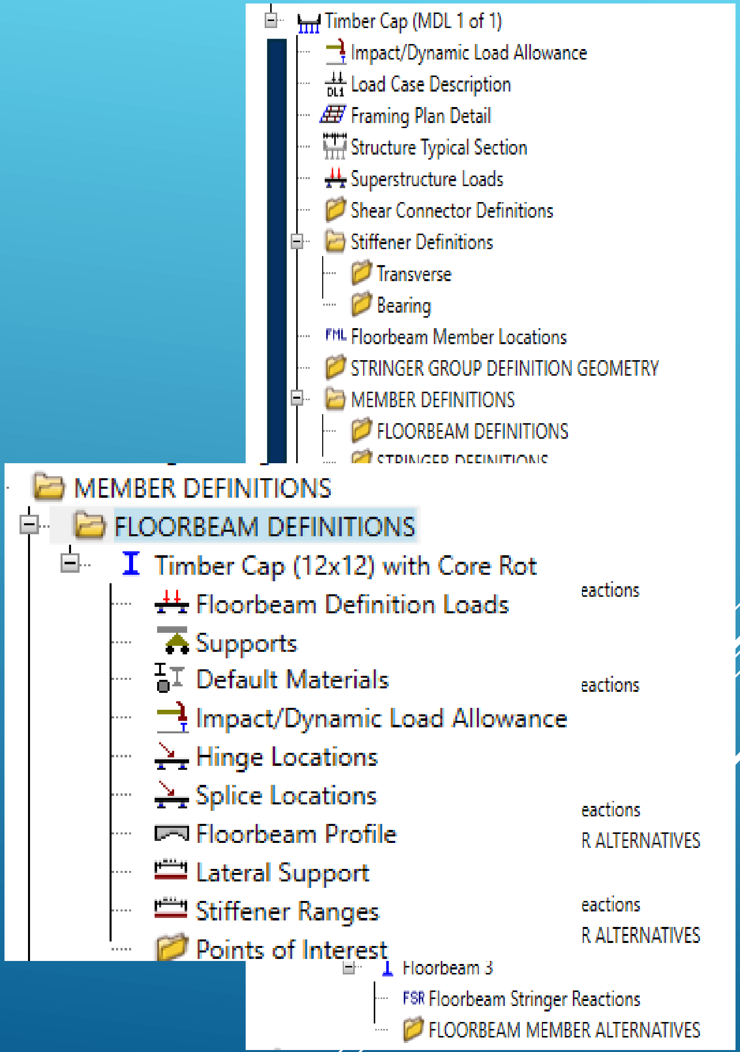




MODELING THE TIMBER CAP

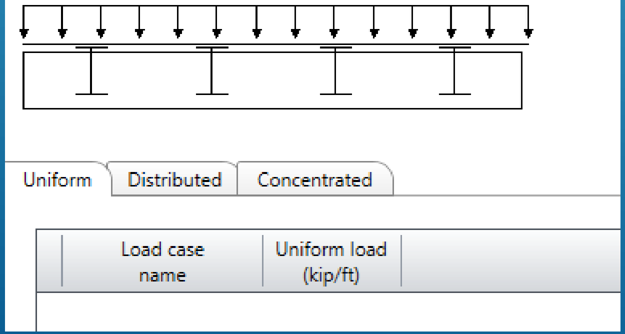
- 2.1 Create a **FS Model** Cont'd
  - 2.1.10 FLOORBEAM DEFINITIONS
    - Change the Control Options to load rate only at the user defined points

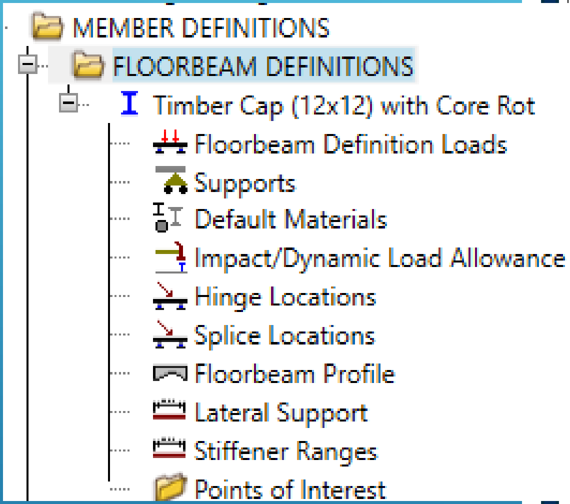


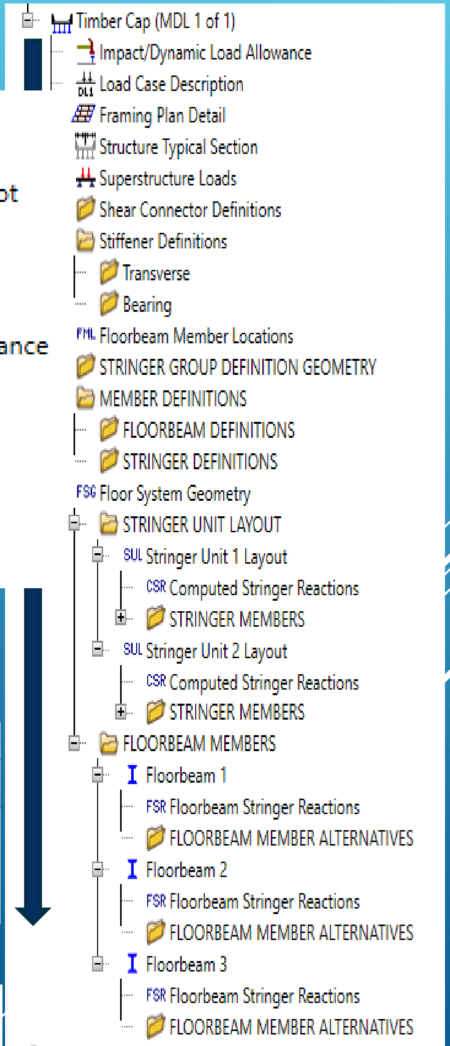


MODELING THE TIMBER CAP

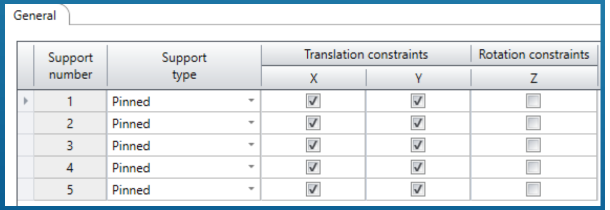
- 2.1 Create a **FS Model** Cont'd
  - 2.1.10 FLOORBEAM DEFINITIONS Cont'd
    - 2.1.10.1: Loads: If any additional loads are directly placed on the bent cap enter it using Fl beam Definition Loads



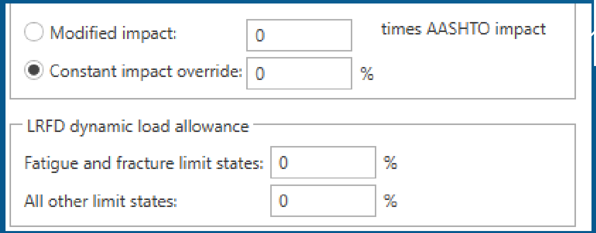




    - 2.1.10.2: View the supports conditions and adjust if needed

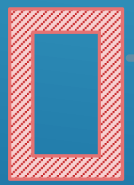


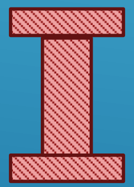
    - 2.1.10.4 Ensure that DLA is set to zero for Timber CAP

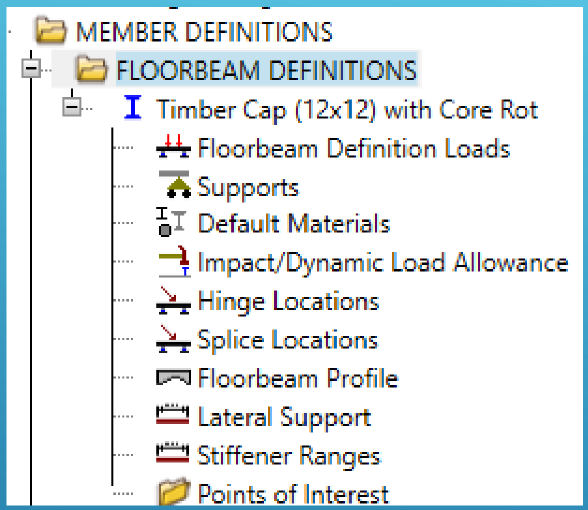


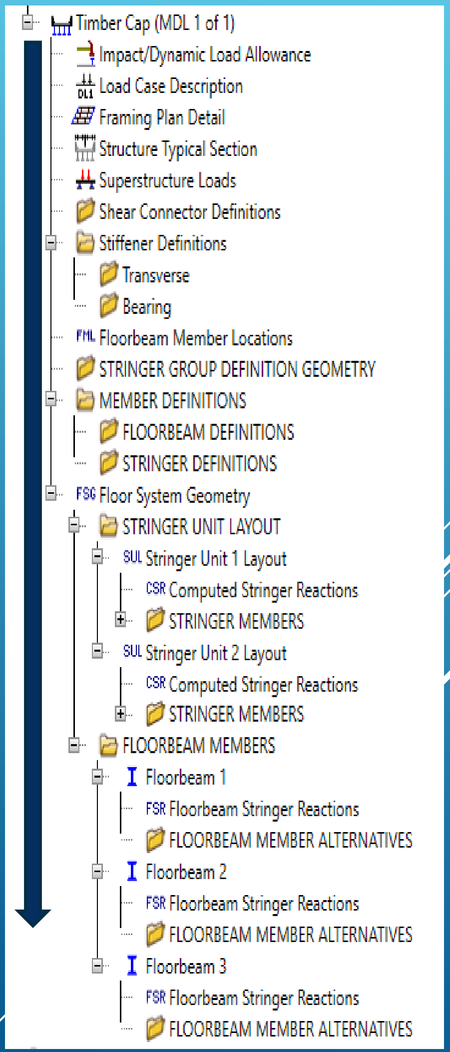
MODELING THE TIMBER CAP

- 2.1 Create a **FS Model** Cont'd
  - 2.1.10 FLOORBEAM DEFINITIONS Cont'd
    - 2.1.10.7 Floorbeam Profile
      - Top and Bottom flanges are 12" x 1.5"
      - Web is 3" x 9" (depth)
    - Use the "user defined" steel Timber 1500 psi (50 pcf)









Web | Top flange | Bottom flange

Begin depth (in)	Depth vary	End depth (in)	Thickness (in)	Start distance (ft)	Length (ft)	End distance (ft)	Material	Weld at right
9	None	9.0000	3.0000	0.00	28.50	28.50	Timber 1500 psi (50pcf)	-- None --

Web | Top flange | Bottom flange

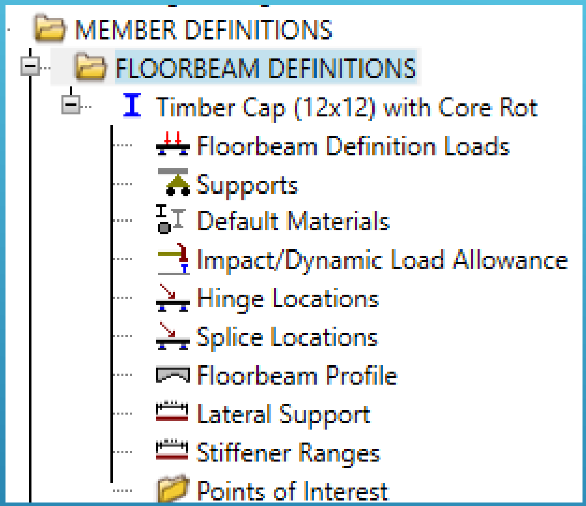
Begin width (in)	End width (in)	Thickness (in)	Start distance (ft)	Length (ft)	End distance (ft)	Material	Weld
12	12.0000	1.5000	0.00	28.50	28.50	Timber 1500 psi (50pcf)	-- None --

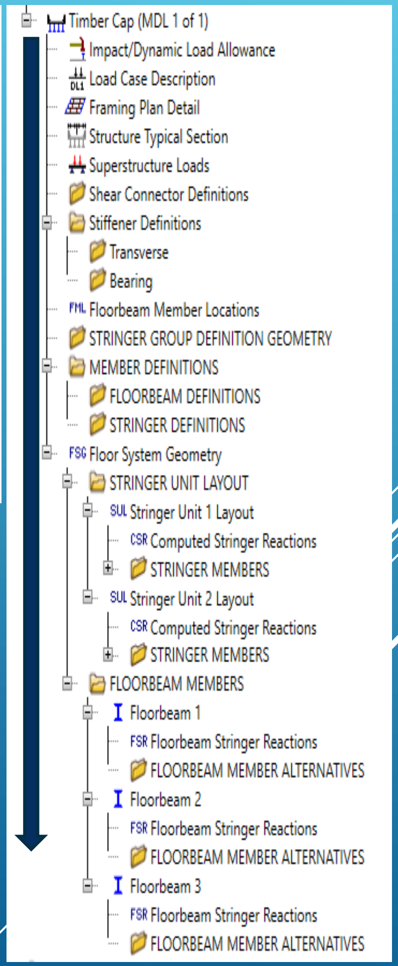
Web | Top flange | Bottom flange

Begin width (in)	End width (in)	Thickness (in)	Start distance (ft)	Length (ft)	End distance (ft)	Material	Weld
12	12.0000	1.5000	0.00	28.50	28.50	Timber 1500 psi (50pcf)	-- None --

MODELING THE TIMBER CAP

- 2.1 Create a FS Model Cont'd
  - 2.1.10 FLOORBEAM DEFINITIONS Cont'd
    - 2.1.10.8 Lateral Support
      - Since capacity overwrite is used, it can be left blank
    - 2.1.10.9 Transverse Stiffeners
      - Again, Since capacity overwrite is used, it can be left blank





MODELING THE TIMBER CAP

- **3.1 Establish ASR Flexure and Shear Capacity**
- Capacity needs to be established outside of the software
  - Inventory and Operating Flexural stress override

The allowable unit stress in bending shall be the tabulated stress adjusted by the applicable adjustment factors given in the following equation:

$$F_b' = F_b C_M C_D C_F C_V C_L C_f C_{fu} C_r \qquad (13\text{-}2)$$

  - Inventory and Operating shear capacity override

$$f_v = \frac{3V}{2bd} \qquad (13\text{-}9)$$

$$F_v' = F_v C_M C_D \qquad (13\text{-}11)$$

$$V_c = (2/3)\ bd\ f_v$$

- Alternatively, By generating a girder line member using timber member, capacity could be established

MODELING THE TIMBER CAP

➢ **3.2 Establish LRFR Flexure and Shear Capacity**

- Capacity needs to be established outside of the software
  - Strength I and Strength II Flexural Capacities

$$F_b = F_{bo}\, C_{KF}\, C_M\, (C_F \text{ or } C_v)\, C_{fu}\, C_i\, C_d\, C_\lambda \qquad (8.4.4.1\text{-}1)$$

$$M_n = F_b S C_L \qquad (8.6.2\text{-}1)$$

$$M_r = \phi M_n \qquad (8.6.1\text{-}1)$$

Flexure .... $\phi = 0.85$
Shear .... $\phi = 0.75$

  - Strength I and Strength II Shear Capacities

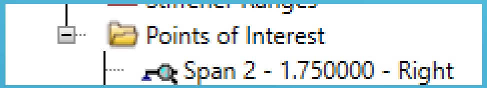
$$F_v = F_{vo}\, C_{KF}\, C_M\, C_i\, C_\lambda \qquad (8.4.4.1\text{-}2)$$

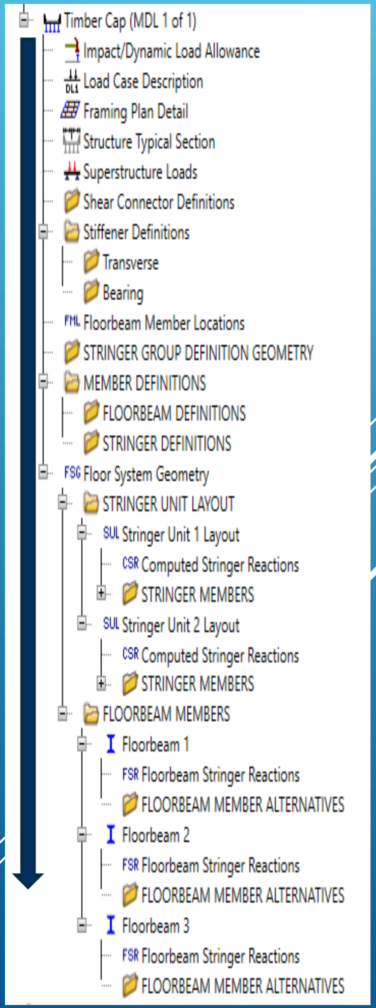
$$V_n = \frac{F_v bd}{1.5} \qquad (8.7\text{-}2)$$

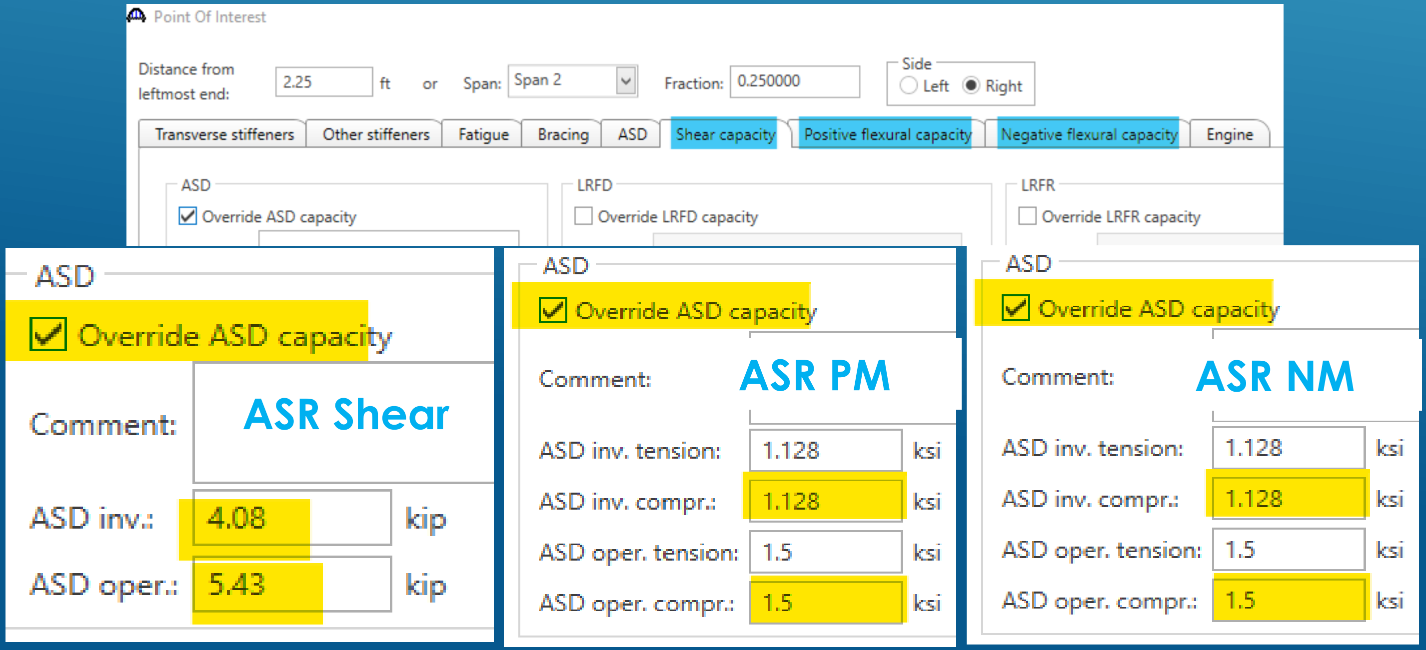
$$V_r = \phi V_n \qquad (8.7\text{-}1)$$

MODELING THE TIMBER CAP

- 2.1 Create a **FS Model** cont'd
  - 2.1.10.10 Floorbeam Points of Interest:
    - Create **one** analysis point and overwrite the capacities for ASR and OR LRFR
    - FOR **ASR** method, the user needs to enter inventory and Operating Capacities for Shear, Positive Flexure and Negative Flexure

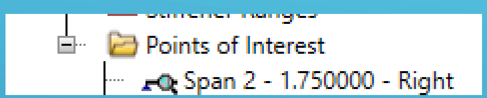


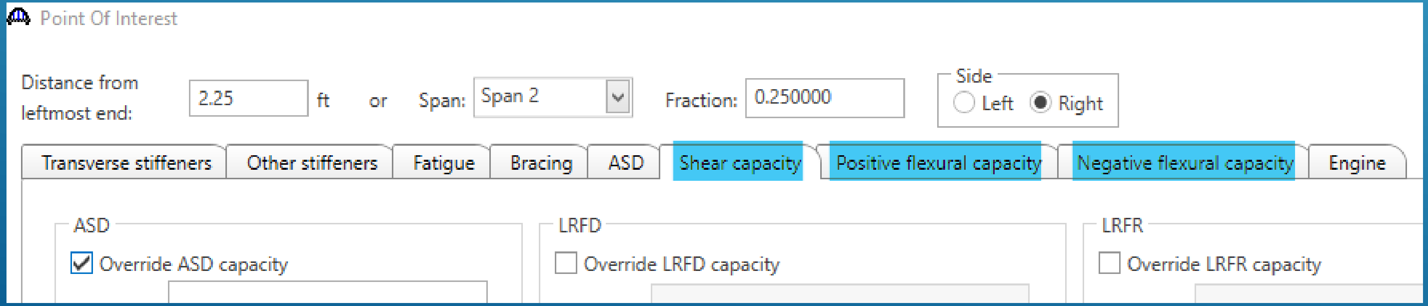




MODELING THE TIMBER CAP

- 2.1 Create a FS Model cont'd
  - 2.1.10.10 Floorbeam Points of Interest:
  - FOR **LRFR** method, the user needs to enter Strength I and Strength II Capacities for Shear, Positive Flexure and Negative Flexure. User need to enter flexural capacity in terms of capacity and maximum stress.





Shear capacity

LRFR Shear

Limit state	Over-ride	(kip)	Phi
STRENGTH-I	☑	13.6	0.75
STRENGTH-II	☑	13.6	0.75
SERVICE-II	☐		
FATIGUE	☐		

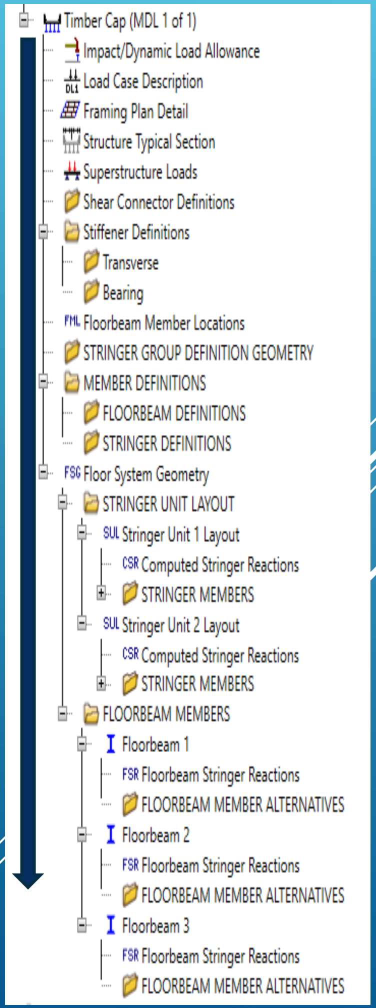
Positive flexural capacity | Negative flexural capacity

LRFR

☑ Override LRFR capacity

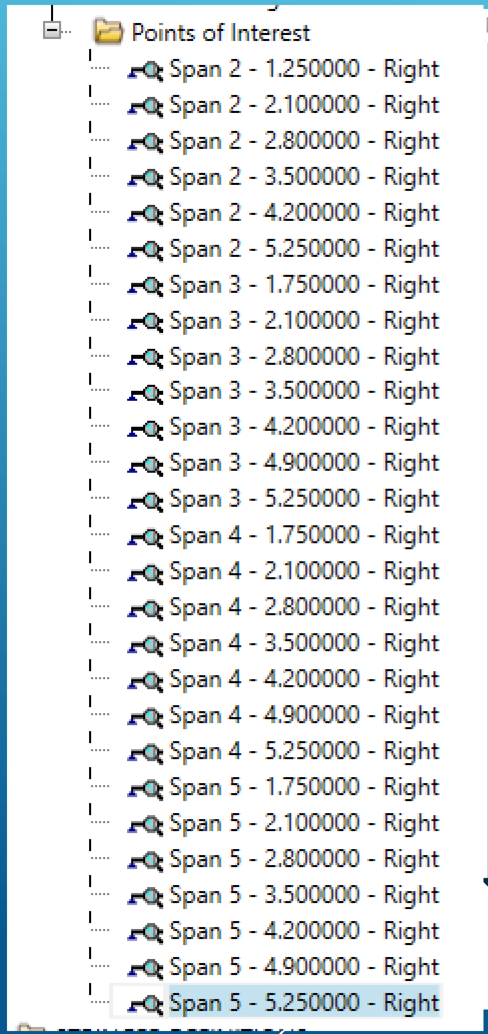
Limit state	Over-ride	Moment capacity (kip-ft)	Tension capacity (ksi)	Compr. capacity (ksi)	Phi
STRENGTH-I	☑	54.43	3.318	3.318	0.85
STRENGTH-II	☑	54.43	3.318	3.318	0.85
SERVICE-II	☐				
FATIGUE	☐				

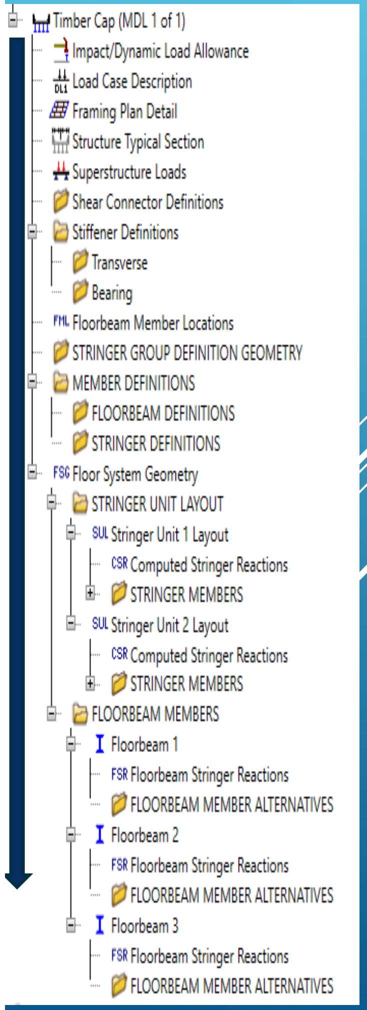
LRFR PM and NM



MODELING THE TIMBER CAP

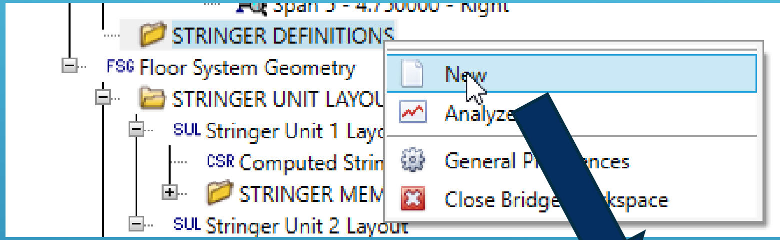
- 2.1 Create a **FS Model** cont'd
  - 2.1.10.10 Floorbeam Points of Interest:
    - Typically, timber member capacity remains the same for the entire length.
    - Once first user-defined points is created and capacities are overwritten, Create **Additional Points of Interest,** by copy/paste or drag/drop approach and modify the analysis point locations to cover
    - ALL 10th points
    - Critical Shear locations
      - Shear Capacity for Caps are established at L/4 (7ft/4 = 1.75ft) or 3.0d = 3ft from face of support
      - Column Support is 12" x 12" therefore, critical shear analysis points will be 1.75ft from CL of supports (girders)
  - Within "d" distance pts from support,
    - Enter a very large shear capacity so that shear will NOT control the rating.
    - This is because, per the Specification, no analysis is needed.

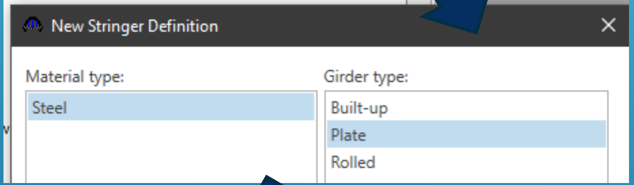


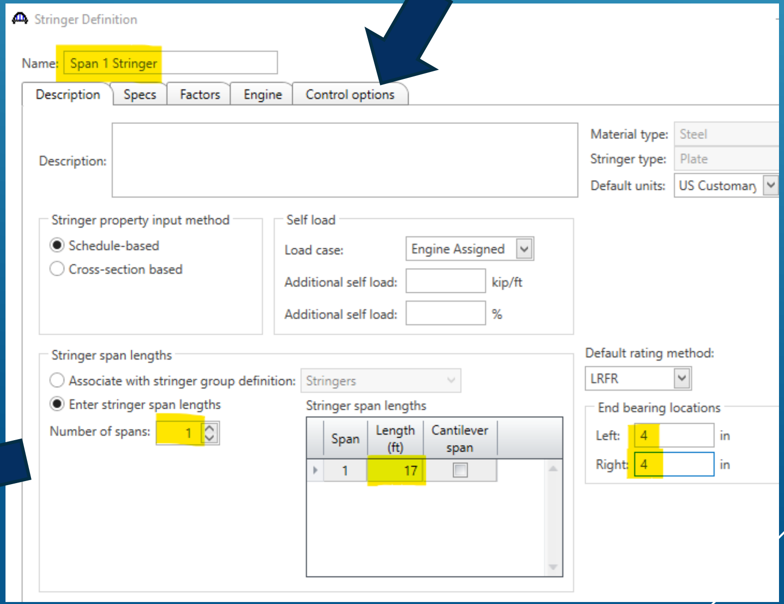


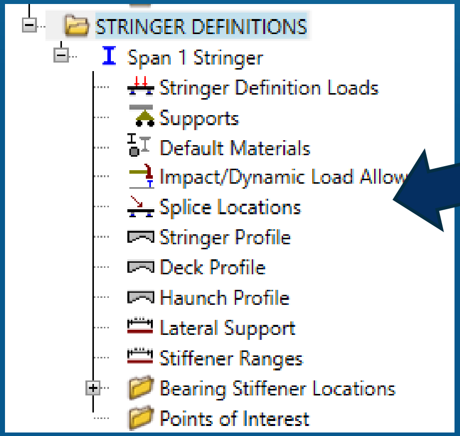
MODELING THE TIMBER CAP

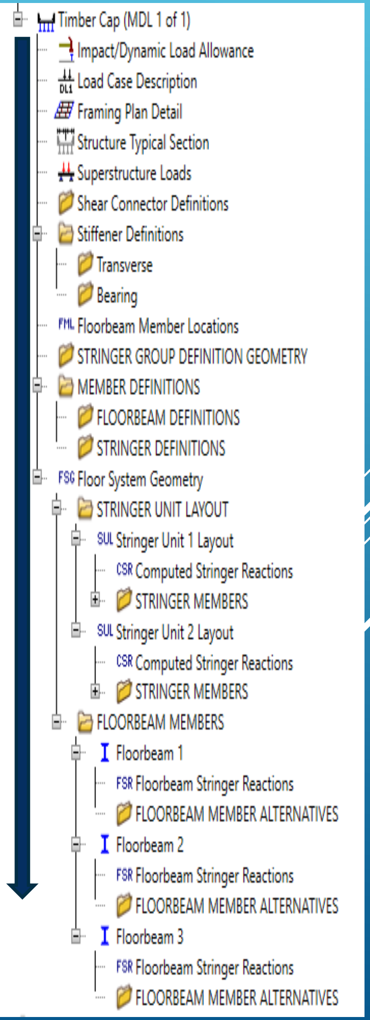
- 2.1 Create a **FS Model** Cont'd
  - 2.1.11 Create STRINGER DEFINITIONS
  - Generate Plate Girder
    - Create NEW
    - Pick the Girder Type Plate
    - Enter the Name (Span 1 Stringer)
    - Number of Span = 1
    - Span Length = 17ft
    - End bearing = 4 in





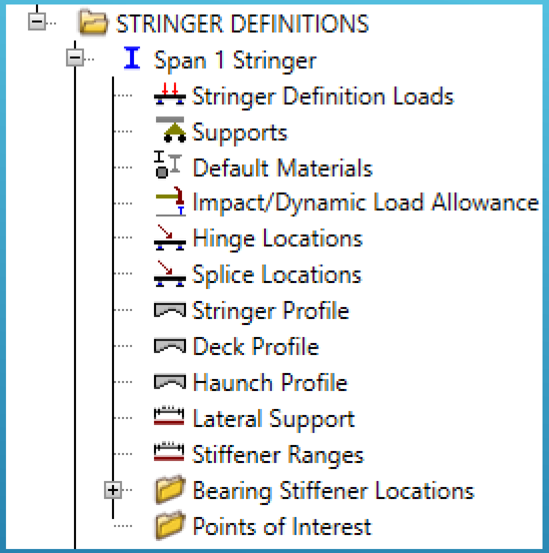






MODELING THE TIMBER CAP

- 2.1 Create a **FS Model** Cont'd
  - 2.1.11.1 Stringer Name: **Span 1 Stringer**
    - Follow the tree and enter the required data.
      - In general, no change is needed **except for the stringer profile**.
  - 2.1.11.7 Stringer Profile:
    - Generate the "Plate Section" that produces a rectangular Timber section (5.75" x 11.00")
    - BrDR software requires web thickness to be less than flange width
    - As a result, the flange width will be increased by 0.005 inches



Type: Plate Girder

Web | Top flange | Bottom flange

Begin depth (in)	Depth vary	End depth (in)	Thickness (in)	Start distance (ft)	Length (ft)	End distance (ft)	Material	Weld at right
9	None	9	5.75	0	17	17	Timber 1500 psi (50pcf)	-- None --

Type: Plate Girder

Web | Top flange | Bottom flange

Begin width (in)	End width (in)	Thickness (in)	Start distance (ft)	Length (ft)	End distance (ft)	Material	Weld	Weld at right
5.755	5.755	1	0	17	17	Timber 1500 psi (50pcf)	-- None --	-- None --

Web | Top flange | Bottom flange

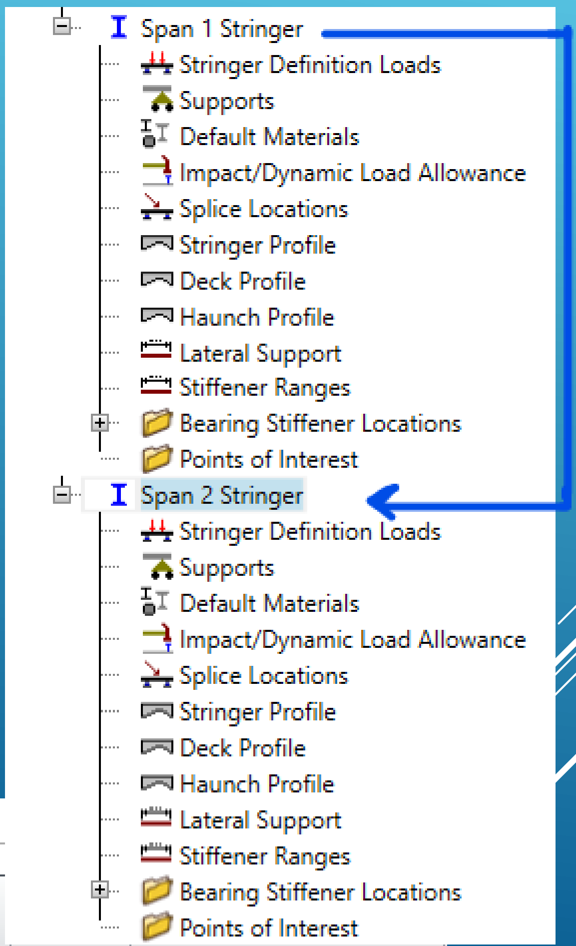
Begin width (in)	End width (in)	Thickness (in)	Start distance (ft)	Length (ft)	End distance (ft)	Material	Weld	Weld at right
5.755	5.755	1	0	17	17	Timber 1500 psi (50pcf)	-- None --	-- None --

MODELING THE TIMBER CAP

- 2.1 Create a **FS Model** Cont'd
  - 2.1.11.2 Create the Stringer Definition for **Span 2 Stringer**
    - Duplicate Stringer Definition Span 1 Stringer and rename to generate Span 2 Stringer profile
    - Adjust the width and depth to match the Stringer size 5.50" x 11.75"
    - Steel Material will be **Timber 1500 psi (50 pcf)**

Web | Top flange | Bottom flange

Begin depth (in)	Depth vary	End depth (in)	Thickness (in)	Start distance (ft)	Length (ft)	End distance (ft)	Material
9.75	None	9.75	5.5	0	17	17	Timber 1500 psi (50pcf)



Web | Top flange | Bottom flange

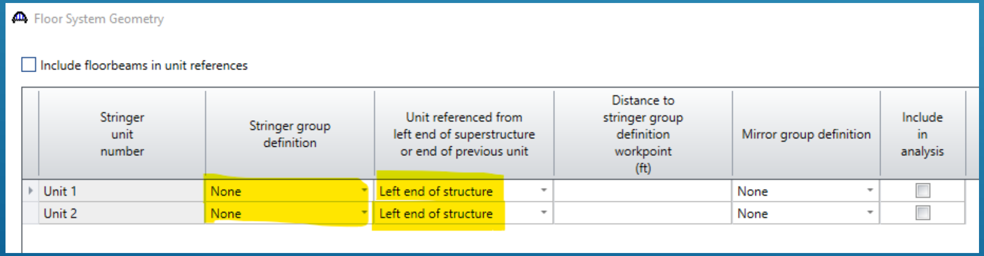
Begin width (in)	End width (in)	Thickness (in)	Start distance (ft)	Length (ft)	End distance (ft)	Material
5.505	5.505	1	0	17	17	Timber 1500 psi (50pcf)

Web | Top flange | Bottom flange

Begin width (in)	End width (in)	Thickness (in)	Start distance (ft)	Length (ft)	(ft)	
5.505	5.505	1	0	17	17	Timber 1500 psi (50pcf)

MODELING THE TIMBER CAP

- 2.1 Create a **FS Model** Cont'd
  - 2.1.12 FSG Floor System Geometry
    - Open the GUI and define the stringer groups that define the flooring arrangements
      - Software produces the following GUI:

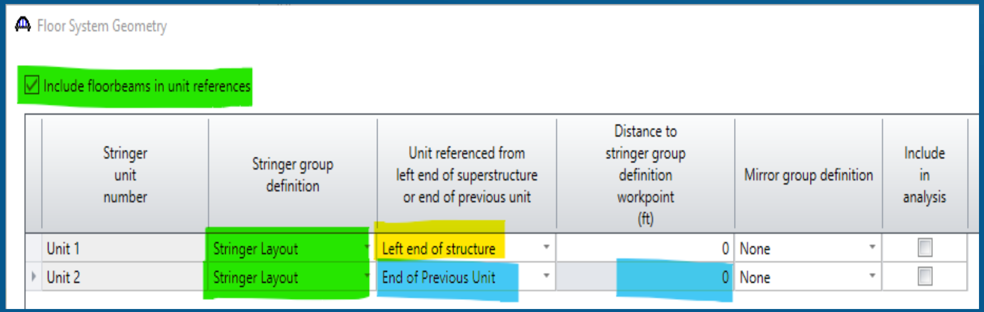


Floor System Geometry

☐ Include floorbeams in unit references

Stringer unit number	Stringer group definition	Unit referenced from left end of superstructure or end of previous unit	Distance to stringer group definition workpoint (ft)	Mirror group definition	Include in analysis
Unit 1	None	Left end of structure		None	☐
Unit 2	None	Left end of structure		None	☐

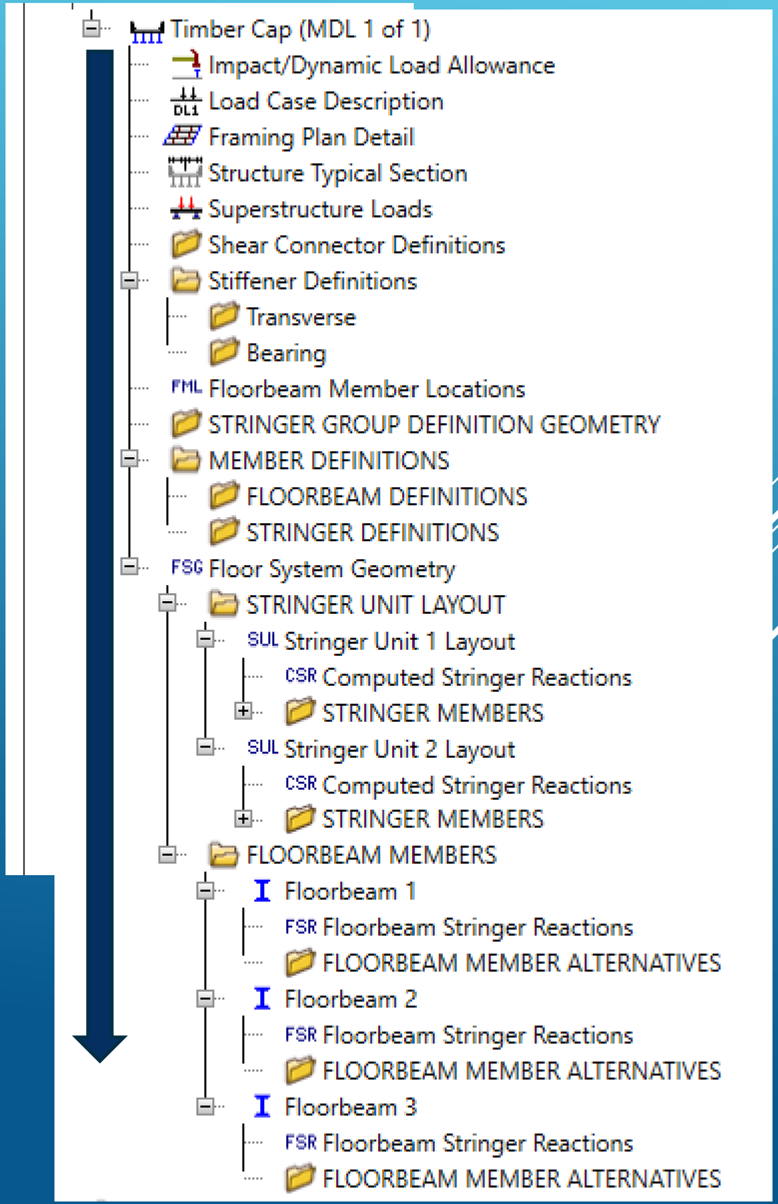
    - The user needs to update it as follows:
      - Do not include in analysis (unchecked)



Floor System Geometry

☑ Include floorbeams in unit references

Stringer unit number	Stringer group definition	Unit referenced from left end of superstructure or end of previous unit	Distance to stringer group definition workpoint (ft)	Mirror group definition	Include in analysis
Unit 1	Stringer Layout	Left end of structure	0	None	☐
Unit 2	Stringer Layout	End of Previous Unit	0	None	☐

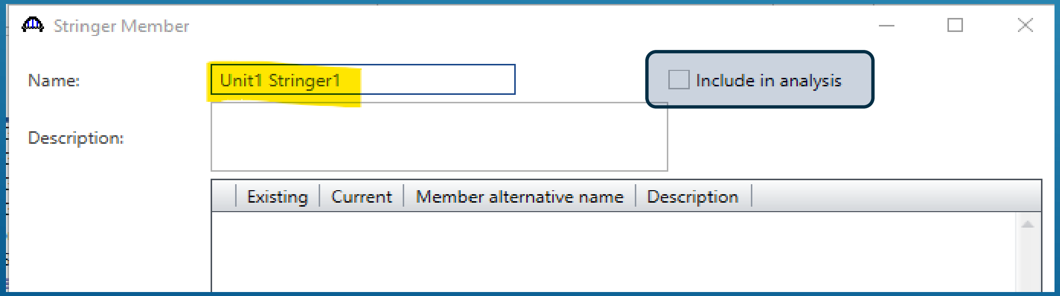


MODELING THE TIMBER CAP

- 2.1 Create a **FS Model** Cont'd

  2.1.12 FSG Floor System Geometry, Cont'd

  - 2.1.12.1 STRINGER MEMBERS
  - Update Uniter Stringer Data
    - Open the Unit 1 Stringer 1
    - Ensure the "include in analysis" unchecked.

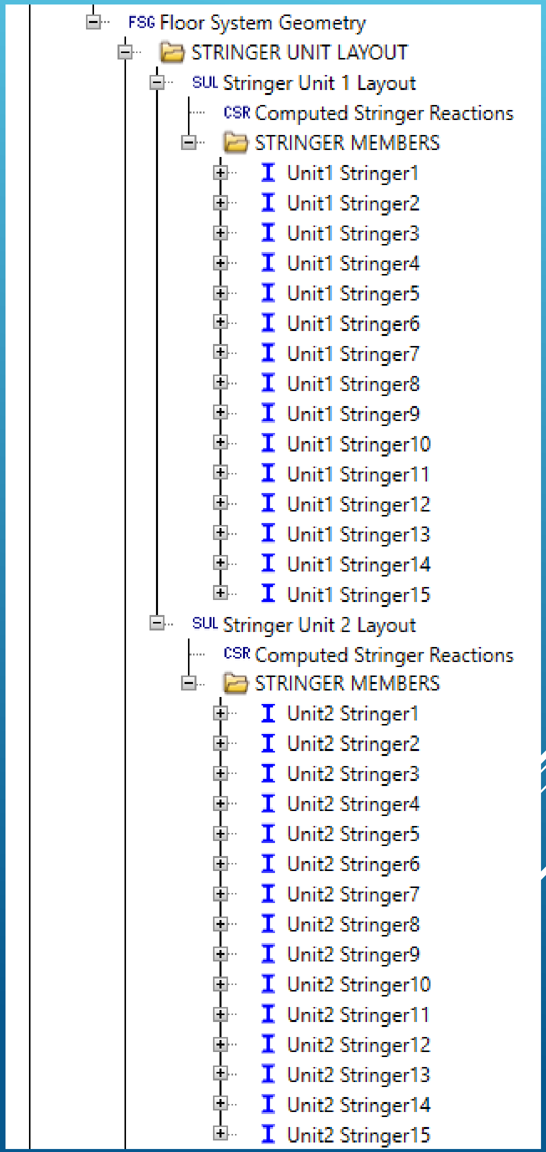


NOTES: The bent cap modeling is a workaround to load rate the bent caps, stringers should **NOT** be included in the analysis.

Software defaults to an "unchecked" case and as a result, the user needs not to visit each stringer GUI.

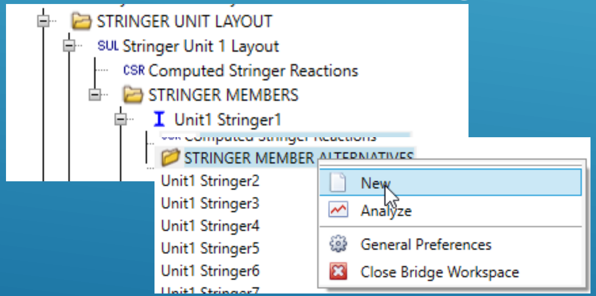
Leave the "include in analysis" unchecked.

Ensure the "include in analysis" is unchecked for all stringer units

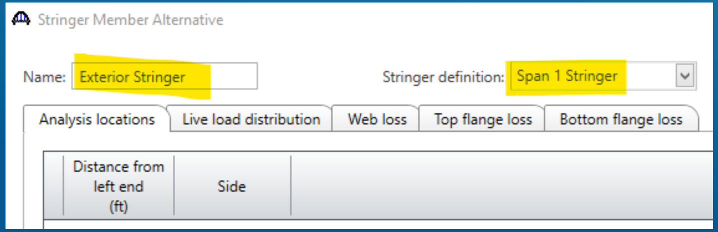


MODELING THE TIMBER CAP

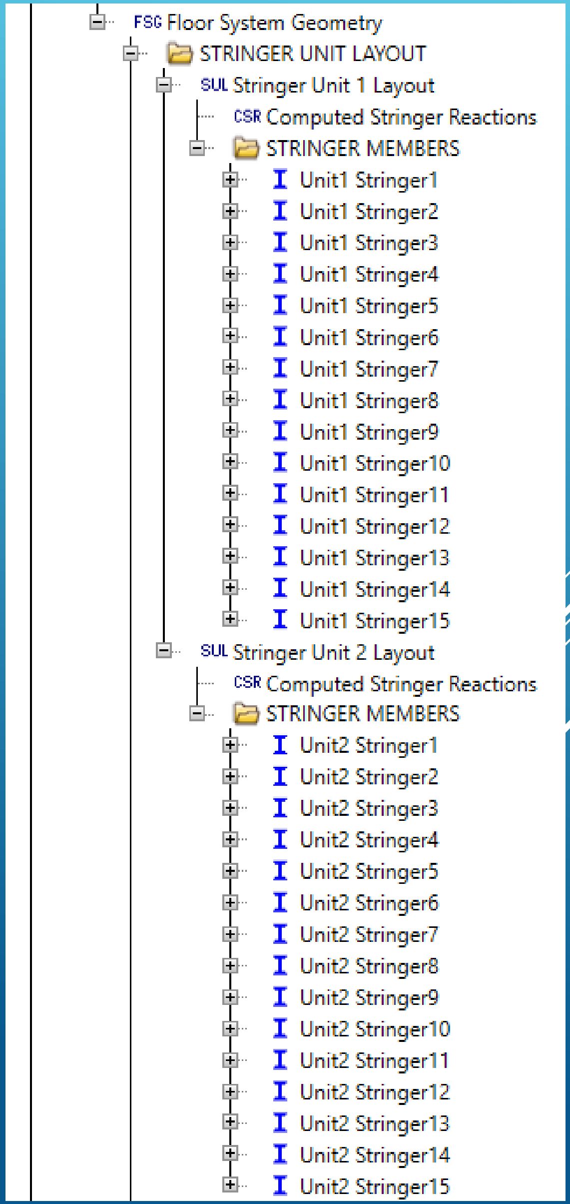
- 2.1 Create a **FS Model** Cont'd
  - 2.1.12 FSG Floor System Geometry, Cont'd
  - 2.1.12.2 Expand the Tree and enter data for each stringer



  - Name the Stringer as Exterior Stringer, Interior Stringer, etc.
    - Example: Select the stringer definition Span 1 Stringer, since span 1 stringers are defined here.

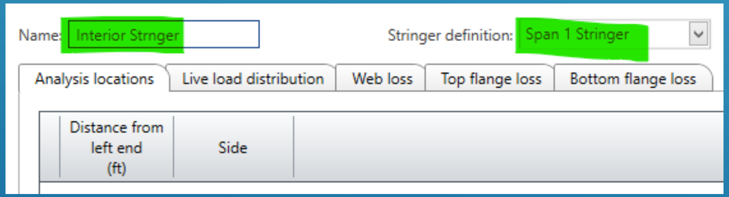


    - NO additional data are to be entered
    - LLDF, Web loss, etc. are not necessary since stringers are NOT load rated.

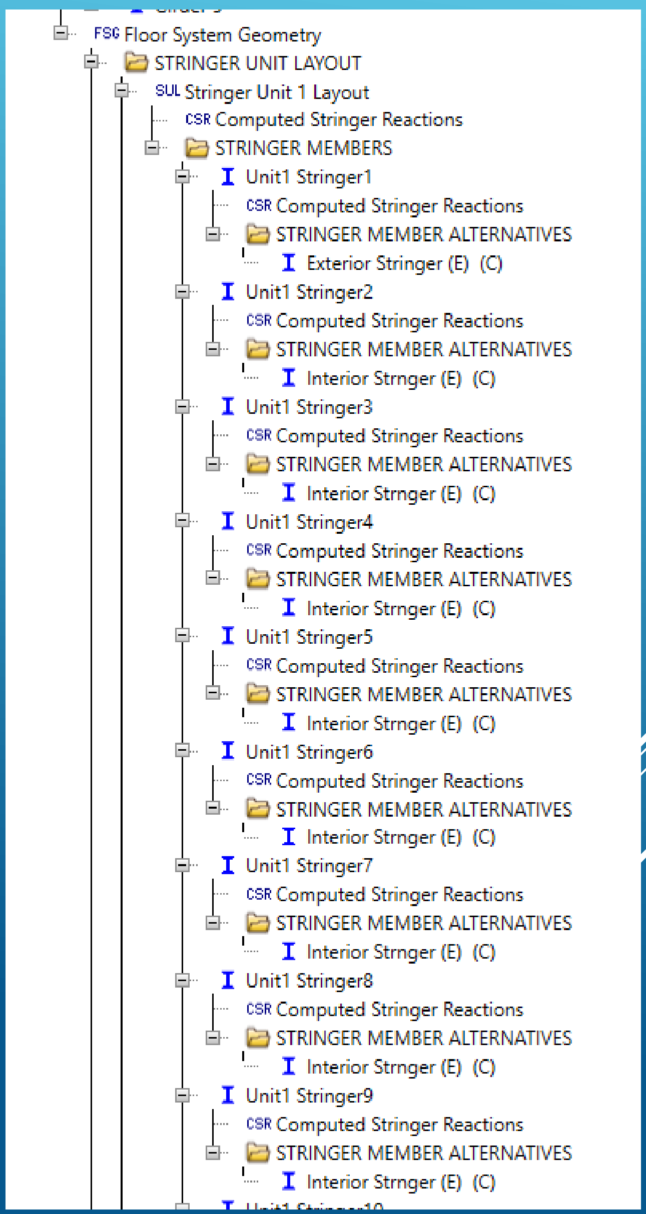


MODELING THE TIMBER CAP

- 2.1 Create a **FS Model** Cont'd
  - 2.1.12 FSG Floor System Geometry, Cont'd
  - 2.1.12.3 Repeat and generate data for all stringers in Span 1

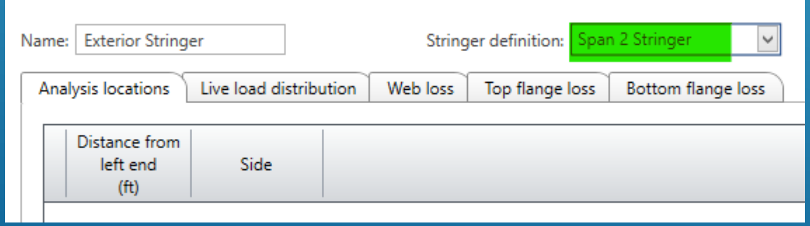


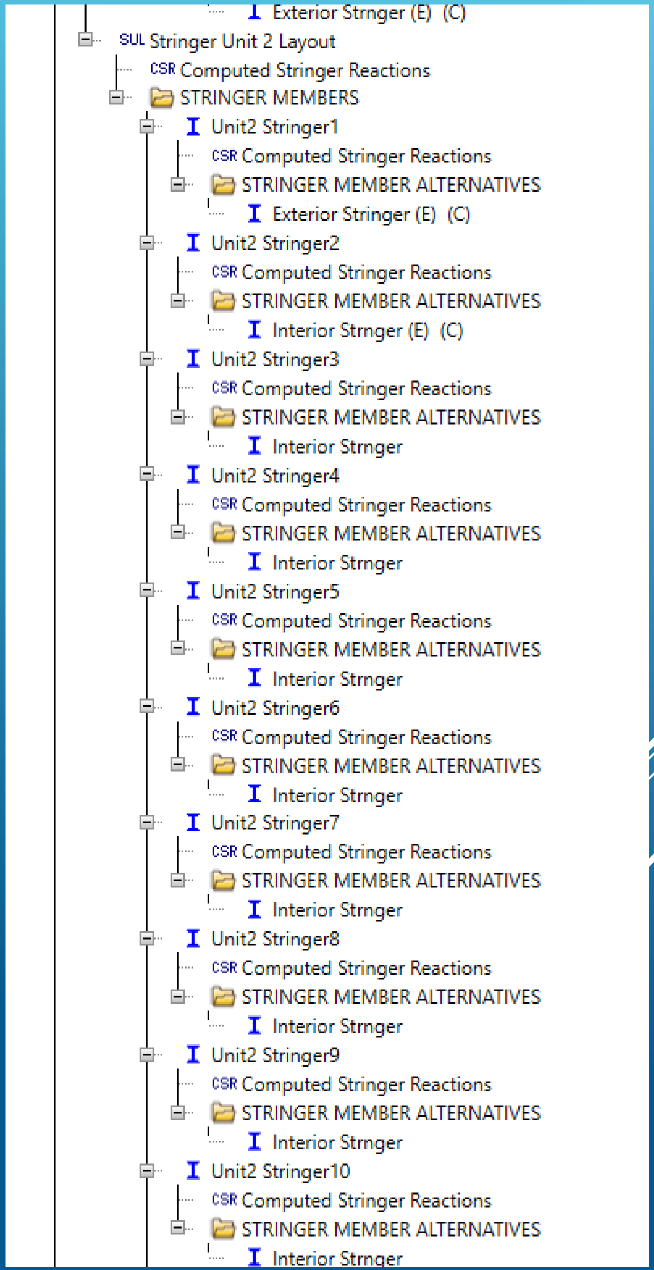
    - Drag and drop the Stringer Member Alternatives of Stringer 2 to all interior stringers may be the faster way to complete this process.
    - NOTE: Each Member alternative be opened, Click OK to Close if drag and drop process is used to ensure data is copied over.
      - This will ensure that existing (E) and current(C) will be assigned to each alternative.



MODELING THE TIMBER CAP

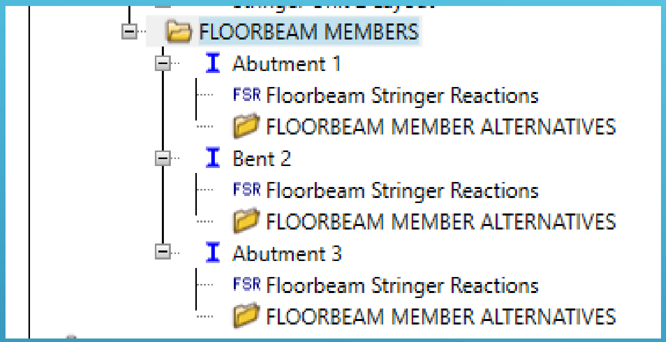
- 2.1 Create a **FS Model** Cont'd
  - 2.1.12 FSG Floor System Geometry, Cont'd
  - 2.1.12.4 Repeat the same process of Stringer Unit 2, where Span 2 stringer be linked.

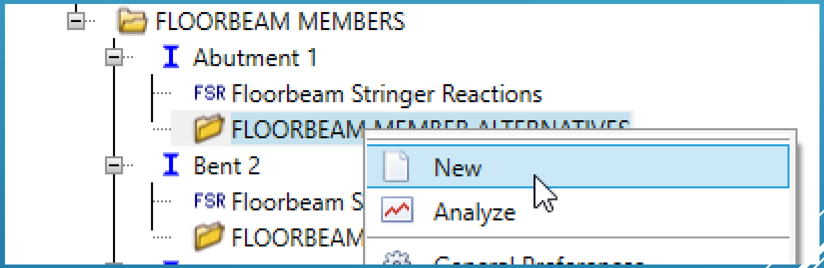


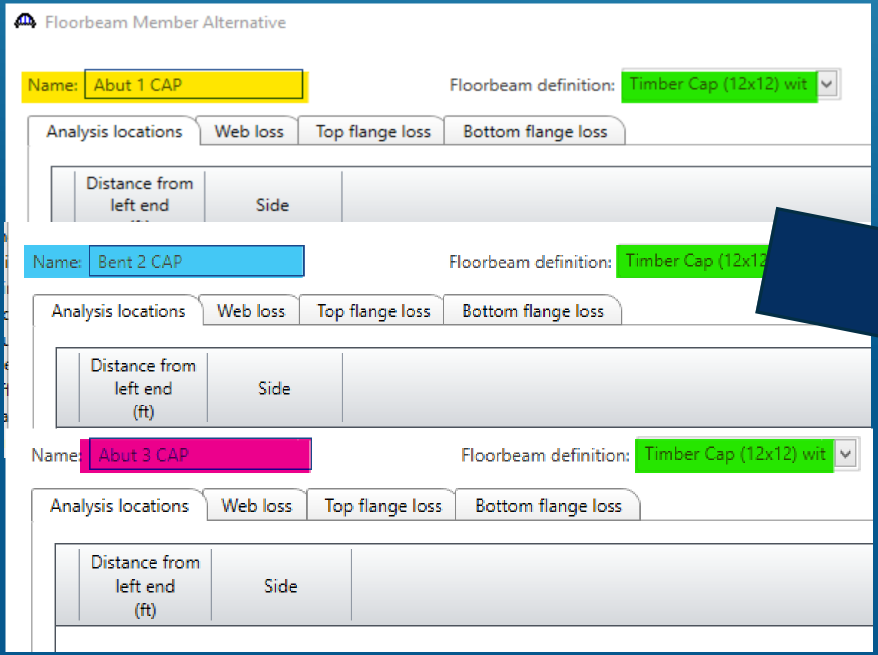


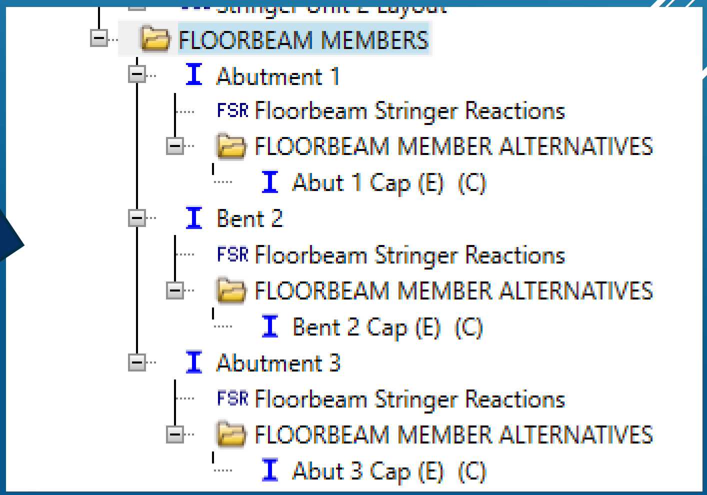
MODELING THE TIMBER CAP

- 2.1 Create a **FS Model** Cont'd
  - 2.1.13 FSG Floor System Members
    - Expand the BrDR Tree
    - User needs to enter Floorbeam member alternatives for Abutment 1, Bent 2 and Abutment 3 by selection Floor beam definitions
      - Create New Alternative



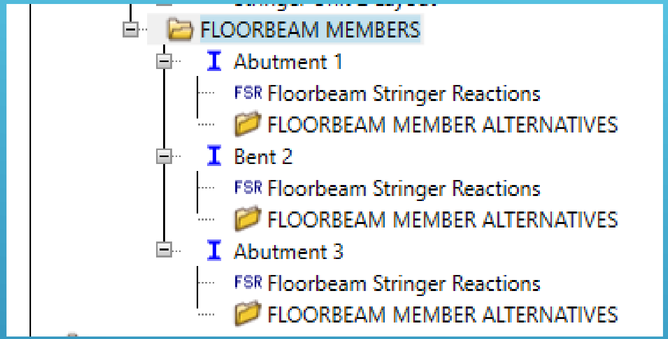


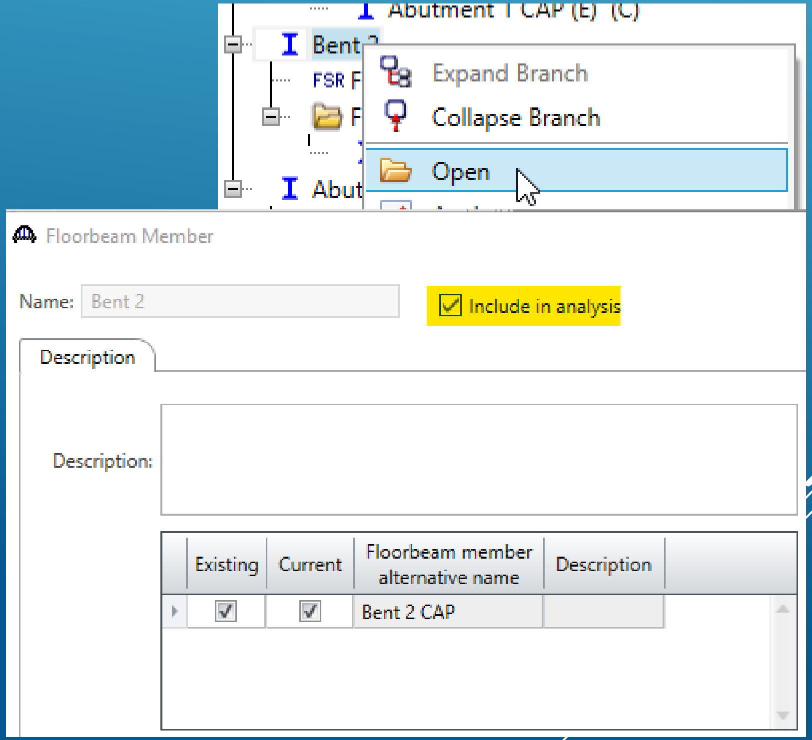




MODELING THE TIMBER CAP

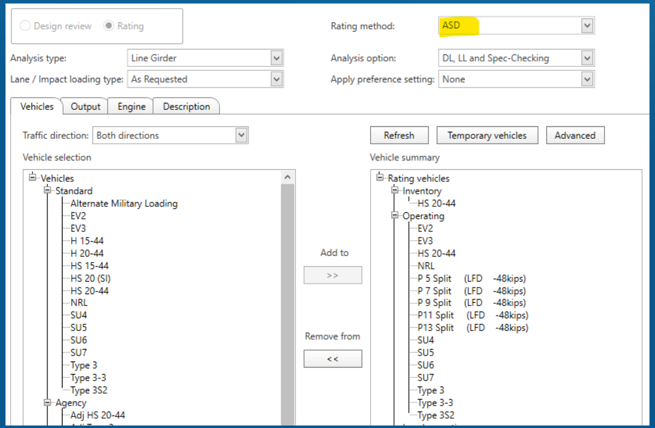
- 2.1 Create a **FS Model** Cont'd
  - 2.1.13 FSG Floor System Members
    - Open the Bent CAP
    - Ensure Analysis of CAP is turned ON.

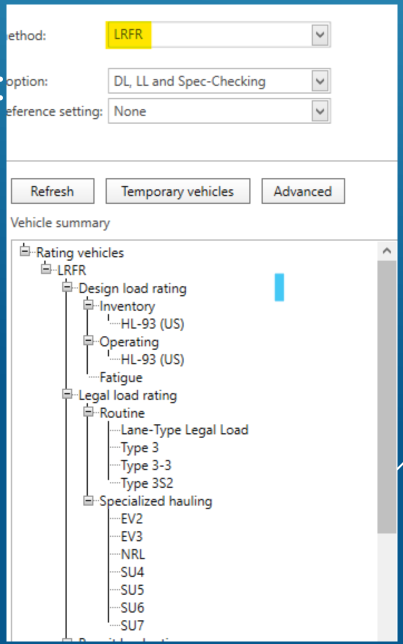




MODELING THE TIMBER CAP

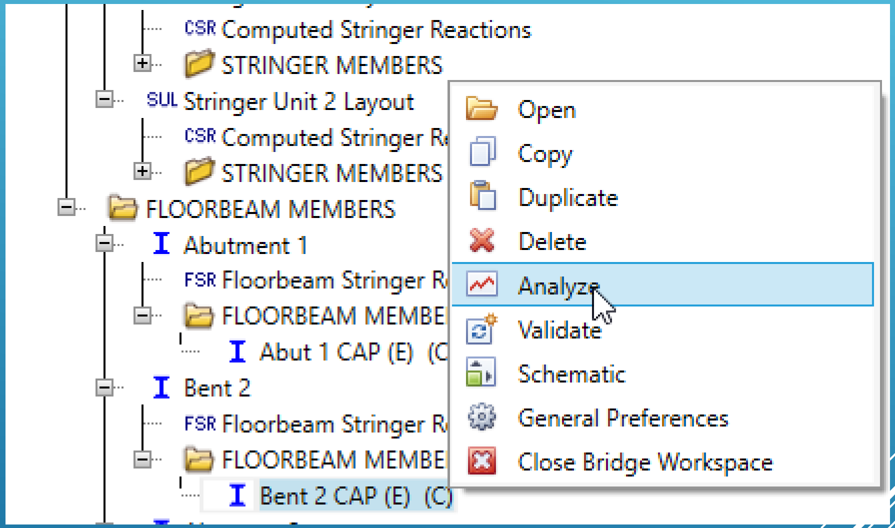
- 4. Bent Cap Analysis
  - “Equivalent” steel girders are used to define the Timber Caps.
  - The ASR and LRFR capacity overwrites are included at each points of interests and there fore, ASR and/or LRFR analysis can be performed.
    - If only the ASR capacity overwrites are entered, only the ASR analysis can be performed.
    - Similarly, if only the LRFR capacity overwrites are entered only the LRFR analysis can be performed
  - Analysis Settings:
    - Analysis setting should be very similar the one shown here:





MODELING THE TIMBER CAP

- 4. Bent Cap Analysis, Cont'd
- With settings, analyze the superstructure
  - Select the Bent 2 CAP member alternative,
  - Rightclick and choose ANALYZE



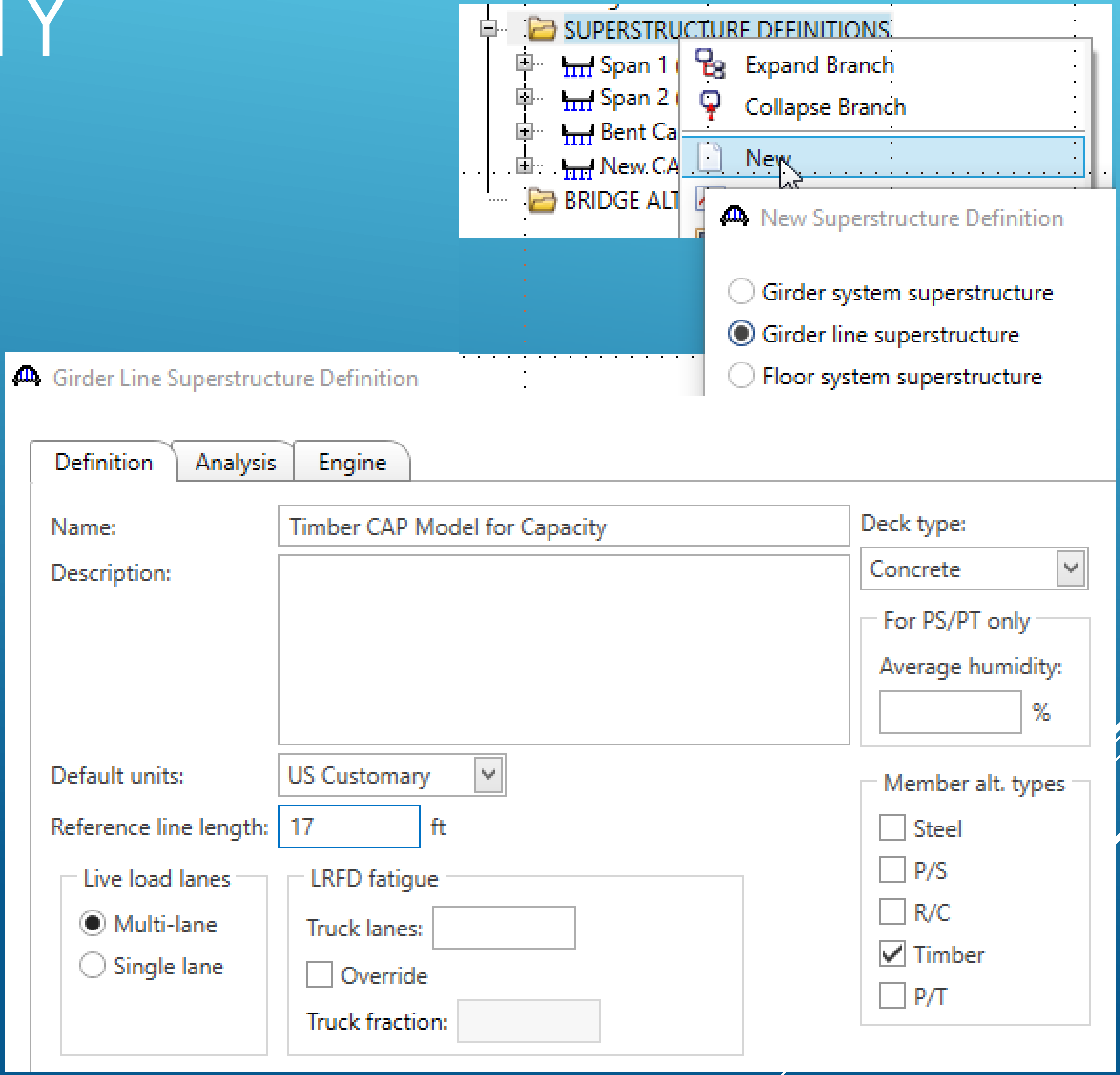
- Load rating based on ASR or LRFR analysis will be performed depending on analysis setting.

MODELING THE TIMBER CAP

- 5. Analysis Results

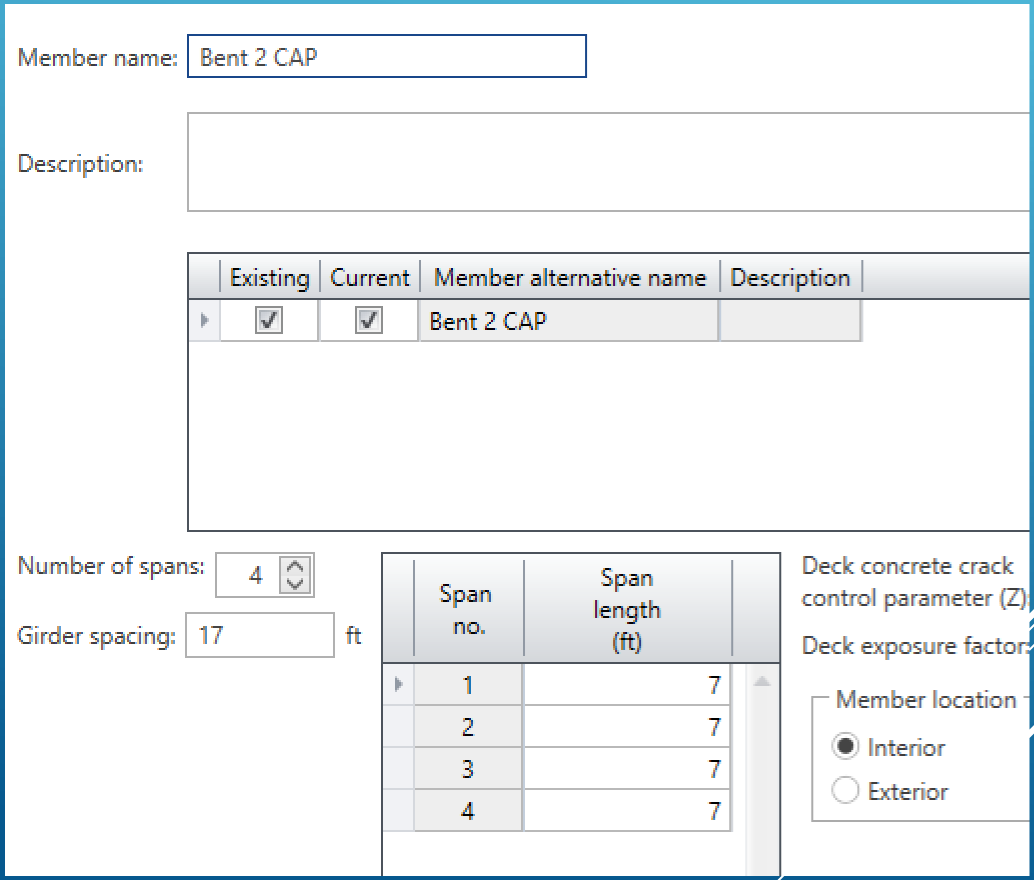
TIMBER CAP CAPACITY

- 1. Create Girder Line CAP
  - Choose Timber.



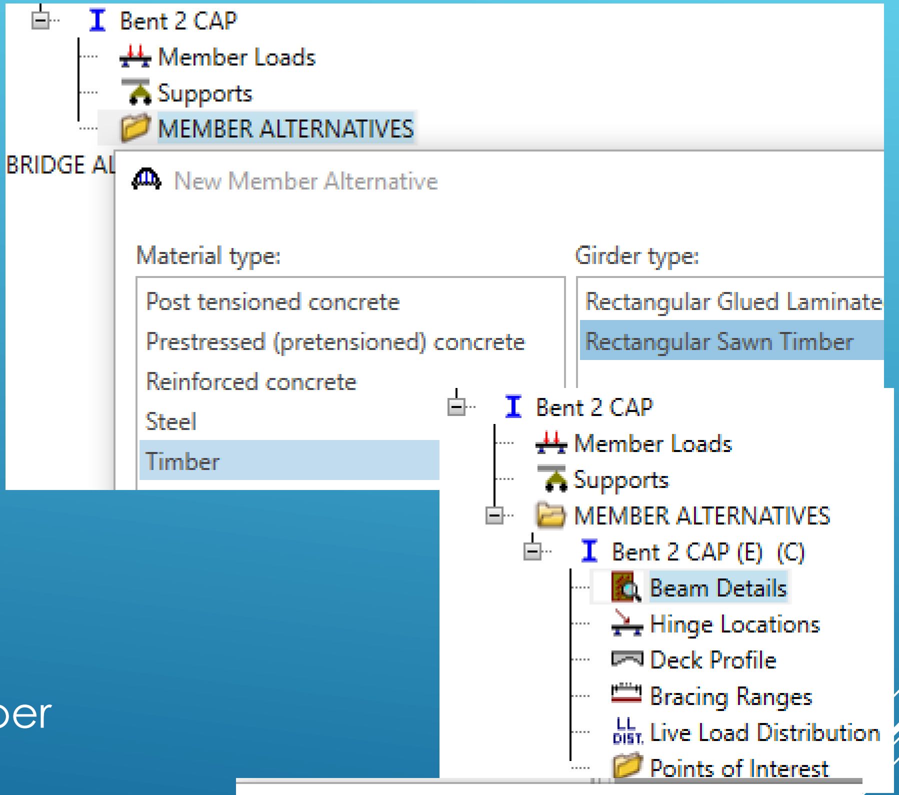
TIMBER CAP CAPACITY

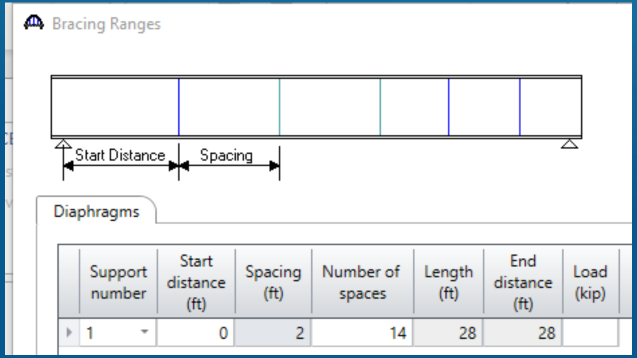
- 1. Create Girder Line CAP Cont'd
  - Tough the CAP has two cantilever portions, the length of cantilever is less than the "d" of the member, it need not be considered
  - So, number of span for this model is 4
  - Span lengths are:
    - 7 ft, 7 ft, 7 ft, and 7ft,
    - Girder spacing = 17 ft (bridge span)

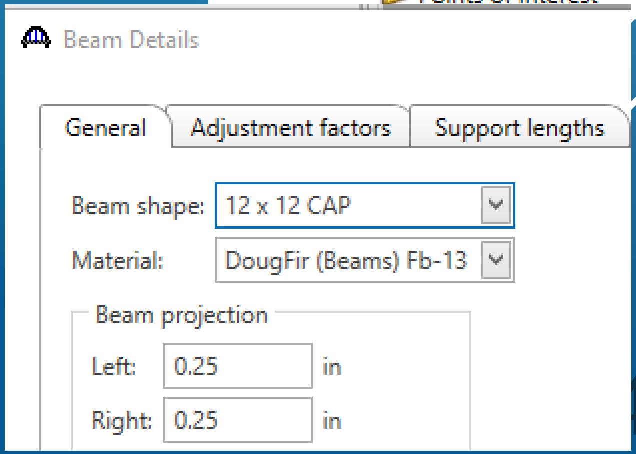


TIMBER CAP CAPACITY

- 1. Create Girder Line CAP Cont'd
  - Create Member Alternative
    - Create Timber Rectangular Sawn Timber Stringer
    - Enter Beam Size, 12 x 12 (original)
    - Enter the Adjustment Factors
    - Enter Bracing Ranges (typically, CAP is braced at timber stringer location by NAILS
      - Bracing plays a role in flexural capacity.

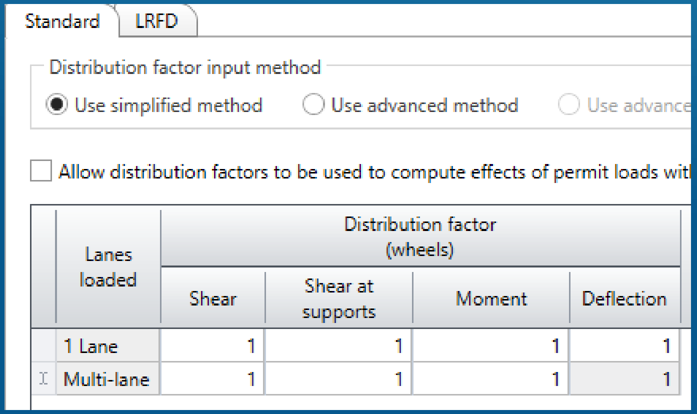


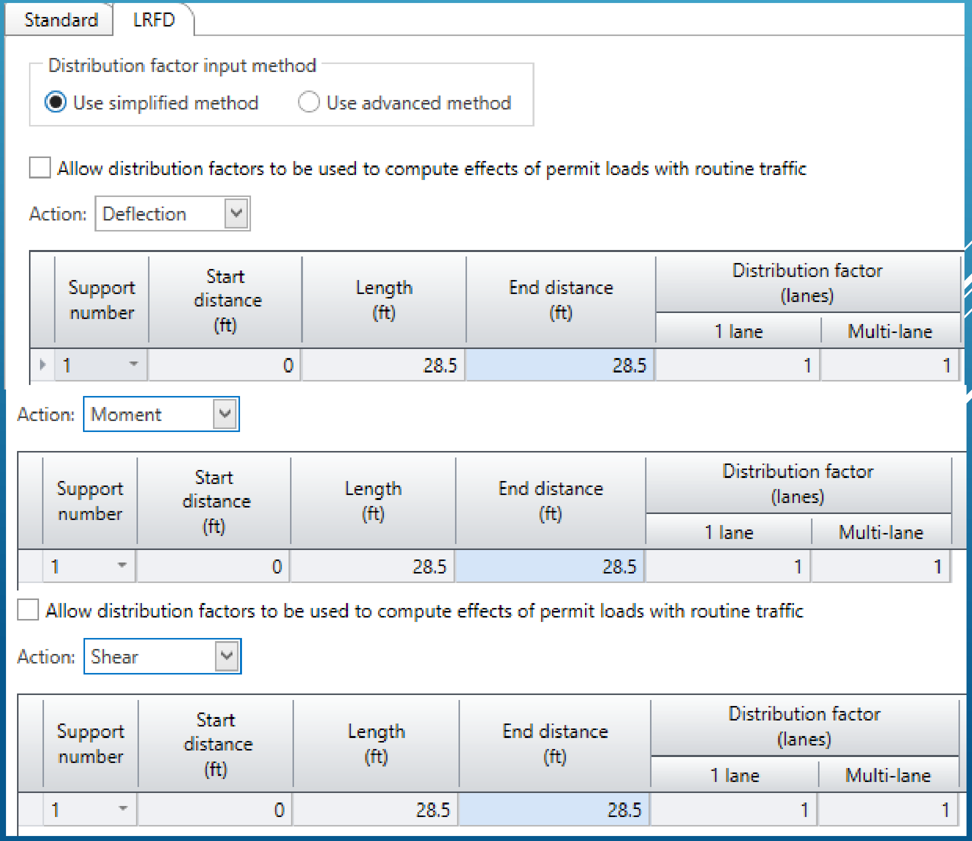




TIMBER CAP CAPACITY

- 1. Create Girder Line CAP Cont’d
  - Finally, enter a LLDF of 1.0 for Standard and LRFD
    - This will allow the software to trigger Specification articles so that capacity will be established.
    - RF established based on this analysis is NOT correct.





TIMBER CAP CAPACITY

- 1. Create Girder Line CAP Cont'd

  - Review the Analysis Output and obtain the capacities established by the software.