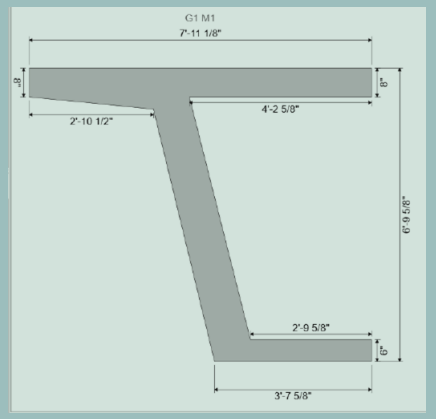
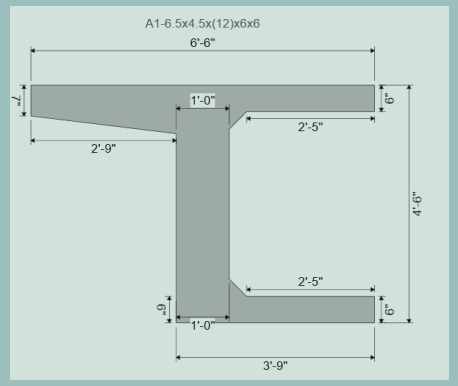
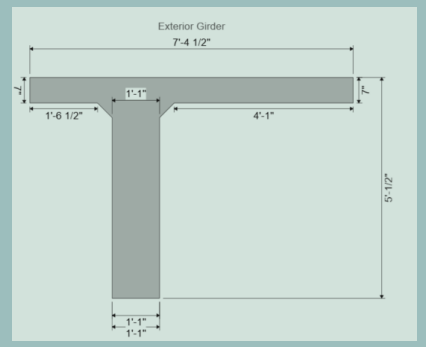


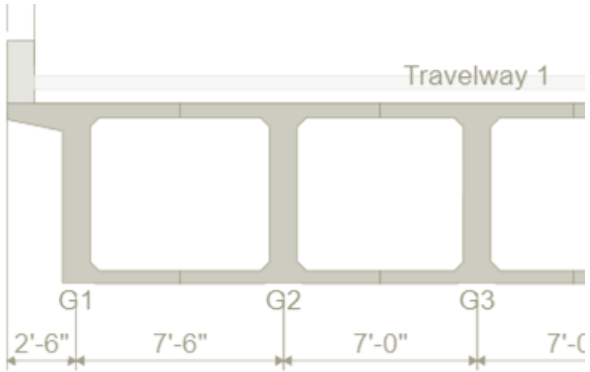
ADVANCED CONCRETE MEMBER (ACM) ALT.

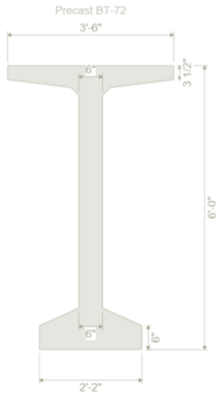
BrDR v 7.1+

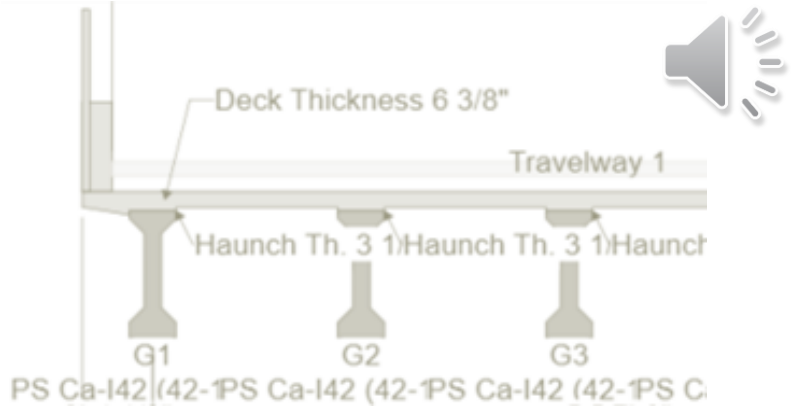




Igor Cherniogl, P.E.







ACM: BRDR VERSION 7.1.0+

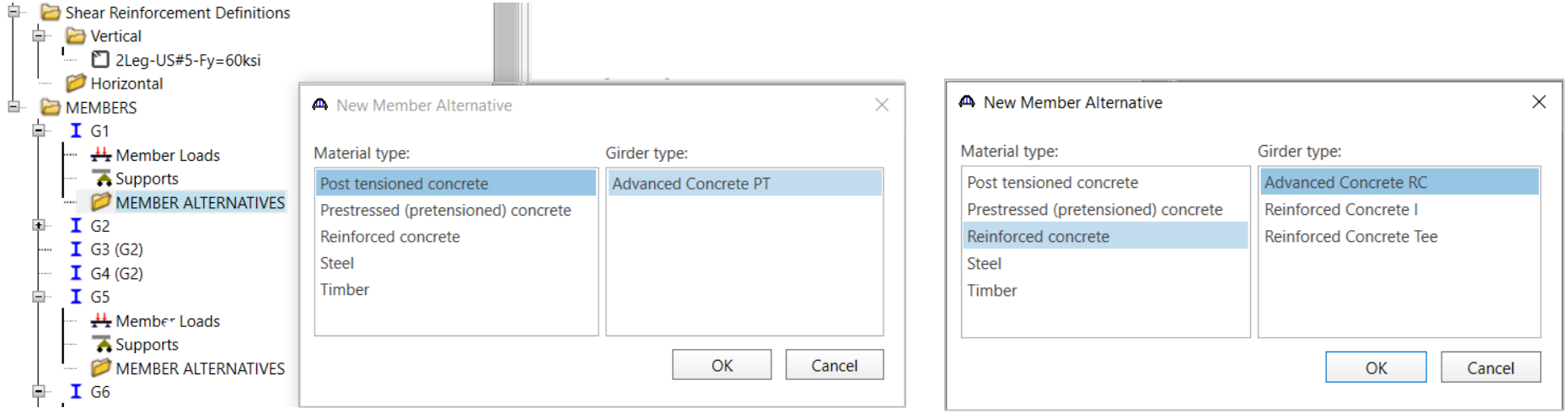
Member alternative in:

- Girder System
- Girder Line

A dvanced

C oncrete

M ember



LIMITATIONS OF OTHER AVAILABLE GIRDER TYPES

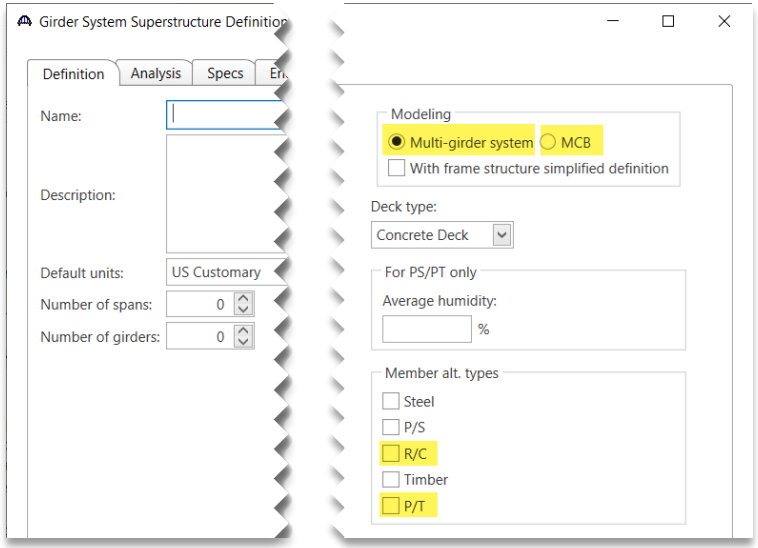
Current limitation of other concrete girder types:

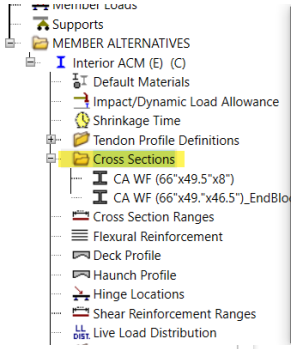
- PT MCB:
  - Unable to analyze individual webs if girder lengths vary ACM ✓
  - Not able to define individual PT paths for each girder or multiple tendon paths ACM ✓
  - Not able to define partial length PT ACM ✓
- Girder System
  - No capability for spliced girders ACM- some capability

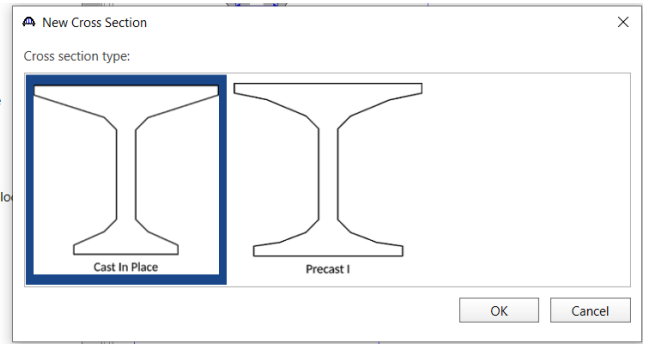
    (Available: Simple for DL, cont. for LL, no PT. Precast girders full span length)
  - No capability for RC precast girders ACM ✓
  - Not able to define post-tensioning ACM ✓
  - Not able to define variable depth precast girders, only one cross section per span ACM ✓

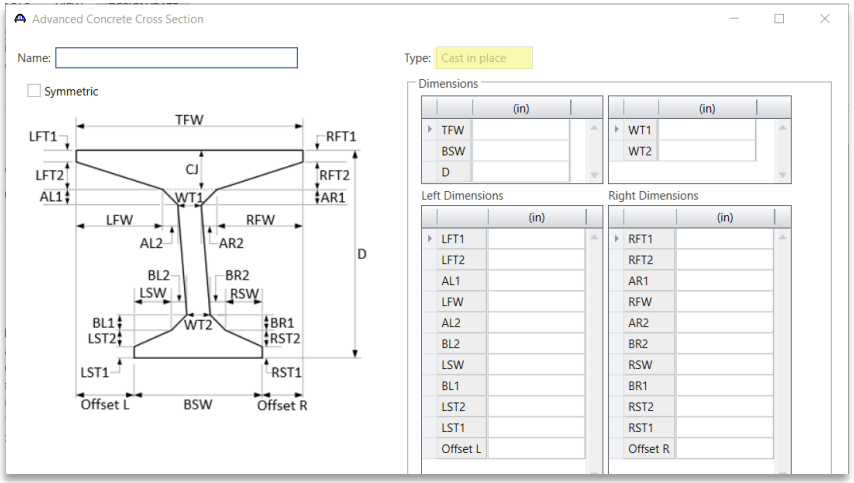
ACM OVERVIEW

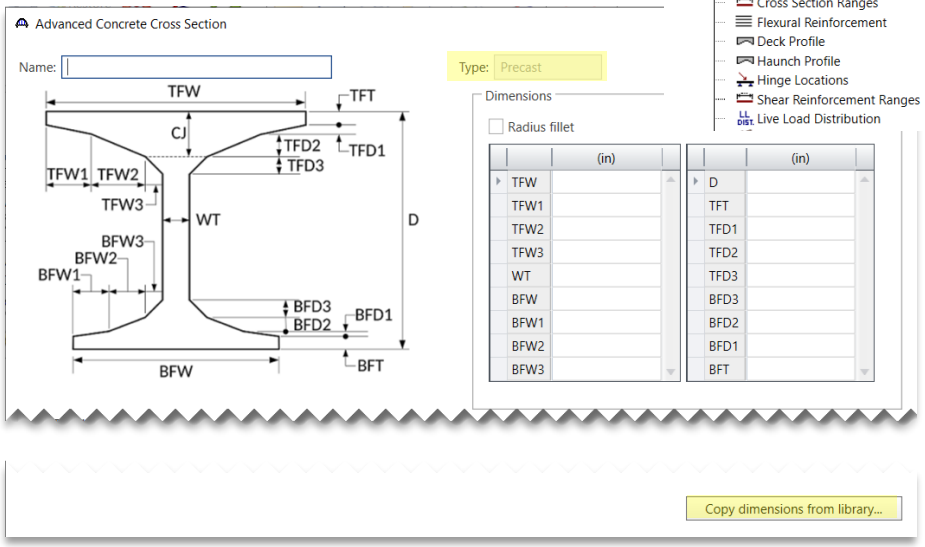
- Built-in modeling versatility:
  - MCB or open girders
  - Reinforced and/or Post-Tensioned
  - Versatile Cross Section Shapes:
    - Cast In Place: user defined
    - Precast I: user defined or import precast 'I' shapes from library





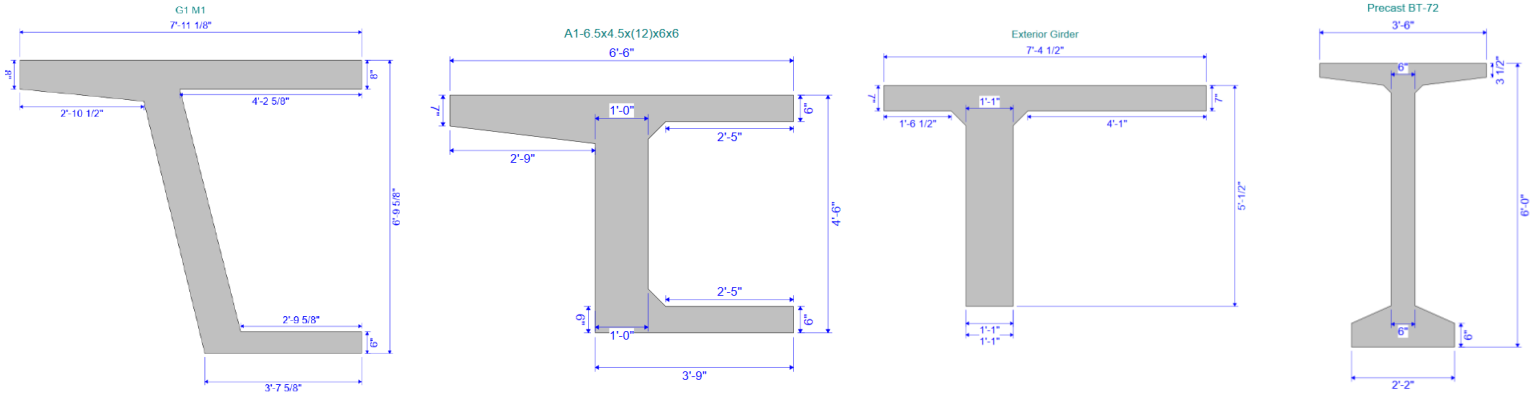


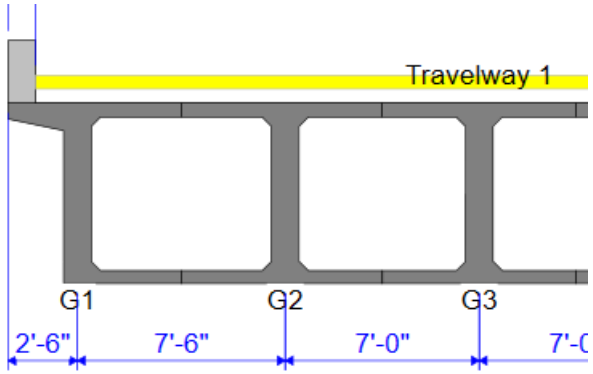


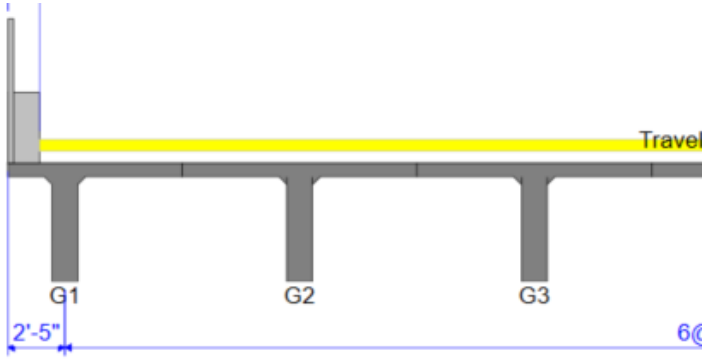


ACM OVERVIEW

- Versatile Cross Section Shapes:



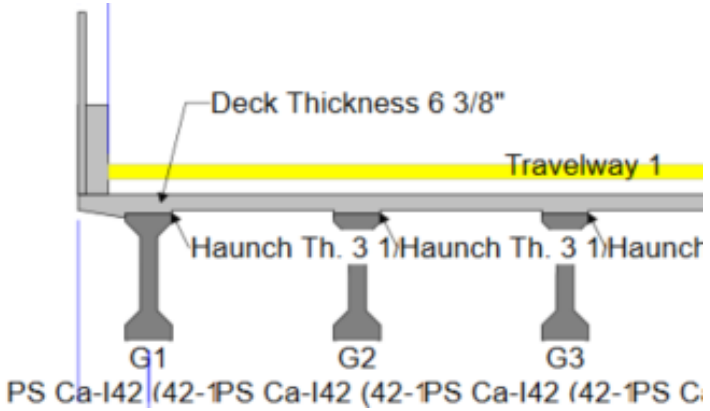




- Hinge with selection for Stage 1, 2, 3 application:
  - Provides ability to model limited construction staging

Hinge

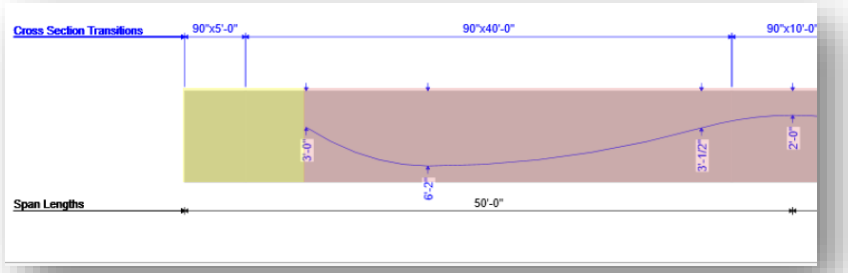
Support number	Hinge location		Consider in stage		
	Left or right of support	Distance (ft)	Non-Composite (Stage 1)	Composite (long term) (Stage 2)	Composite (short term) (Stage 3)
2	Right	24	☑	☐	☐
3	Left	24	☑	☐	☐

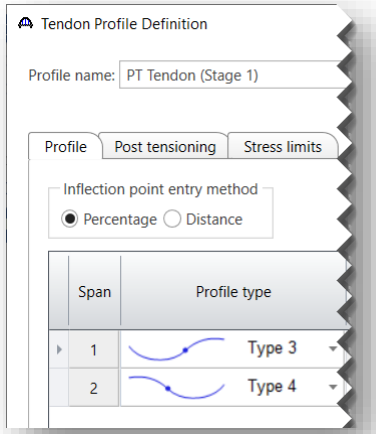


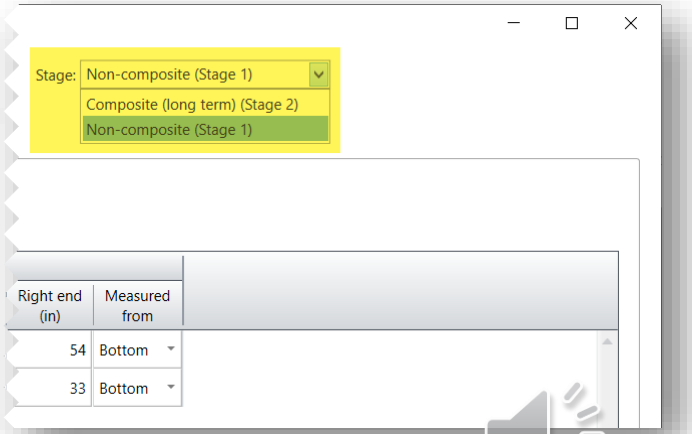
ACM OVERVIEW

PT Prestressing:

- Partial length tendons
  - Cross sections with tendon analyzed as prestressed
  - Cross sections without tendon analyzed as reinforced
- Multiple tendon paths
  - Stacked or overlapping tendons
- Staged Construction, apply to
  - Stage 1 (non-composite) or
  - Stage 2 (composite)

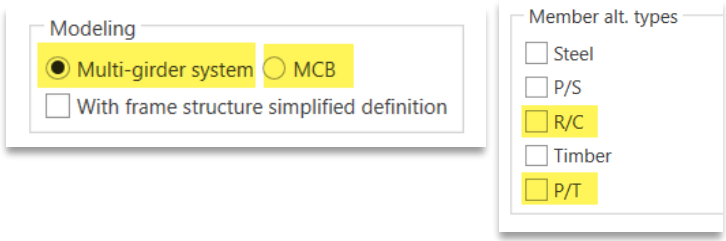






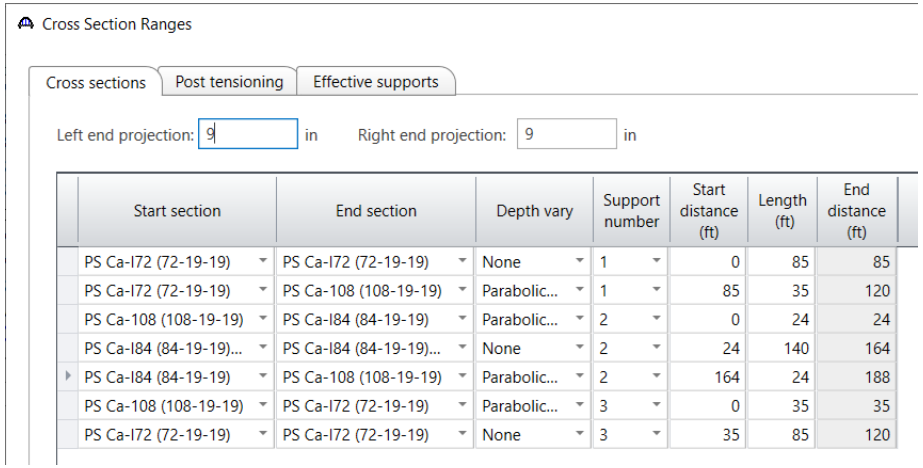
Current limitation: only post-tensioning or RC

ACM OVERVIEW

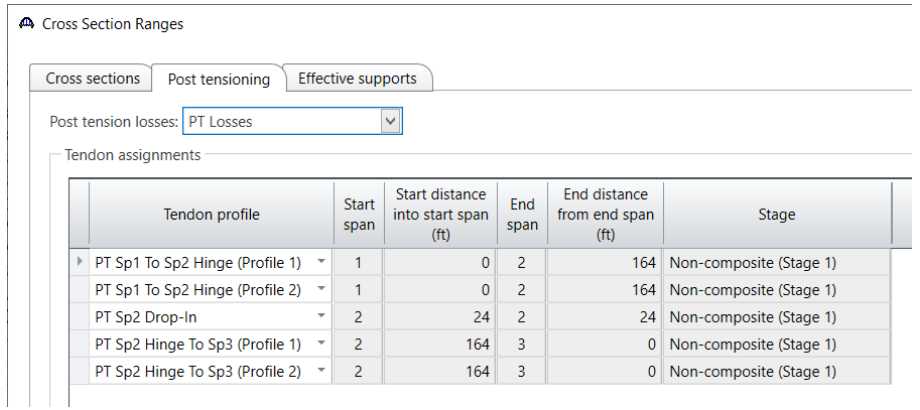


Tree similar to other Girder System superstructures:

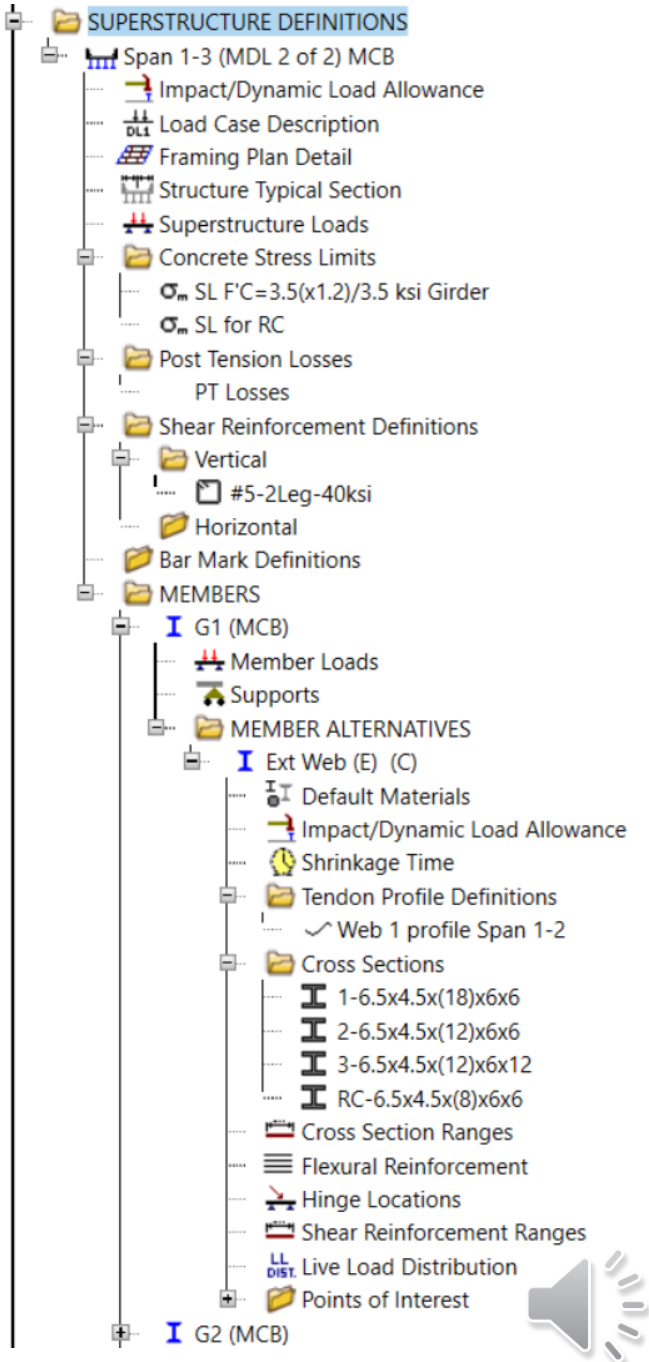
- In Superstructure Definition, choose RC and/or PT to make ACM available in tree
- Available only if PT chosen:
  - Concrete Stress Limits
  - Post Tension Losses
  - Tendon Profile
- Cross Sections
  - Cast In Place or Precast shapes
- Cross Section Ranges
  - Apply defined cross sections
  - Apply defined tendons if PT



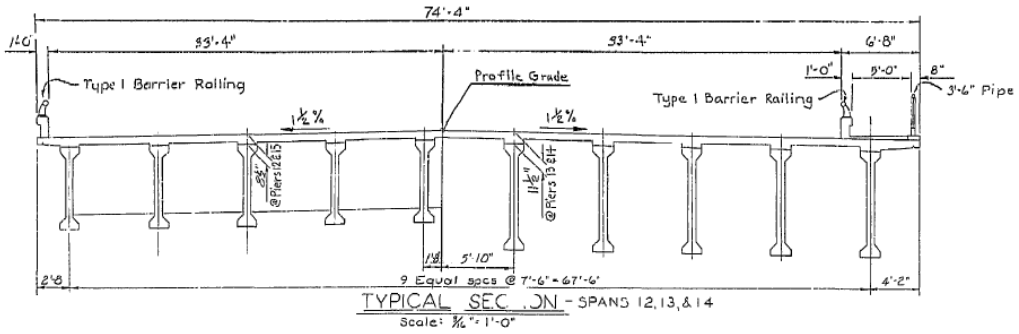
Start section	End section	Depth vary	Support number	Start distance (ft)	Length (ft)	End distance (ft)
PS Ca-I72 (72-19-19)	PS Ca-I72 (72-19-19)	None	1	0	85	85
PS Ca-I72 (72-19-19)	PS Ca-108 (108-19-19)	Parabolic...	1	85	35	120
PS Ca-108 (108-19-19)	PS Ca-I84 (84-19-19)	Parabolic...	2	0	24	24
PS Ca-I84 (84-19-19)...	PS Ca-I84 (84-19-19)...	None	2	24	140	164
PS Ca-I84 (84-19-19)	PS Ca-108 (108-19-19)	Parabolic...	2	164	24	188
PS Ca-108 (108-19-19)	PS Ca-I72 (72-19-19)	Parabolic...	3	0	35	35
PS Ca-I72 (72-19-19)	PS Ca-I72 (72-19-19)	None	3	35	85	120

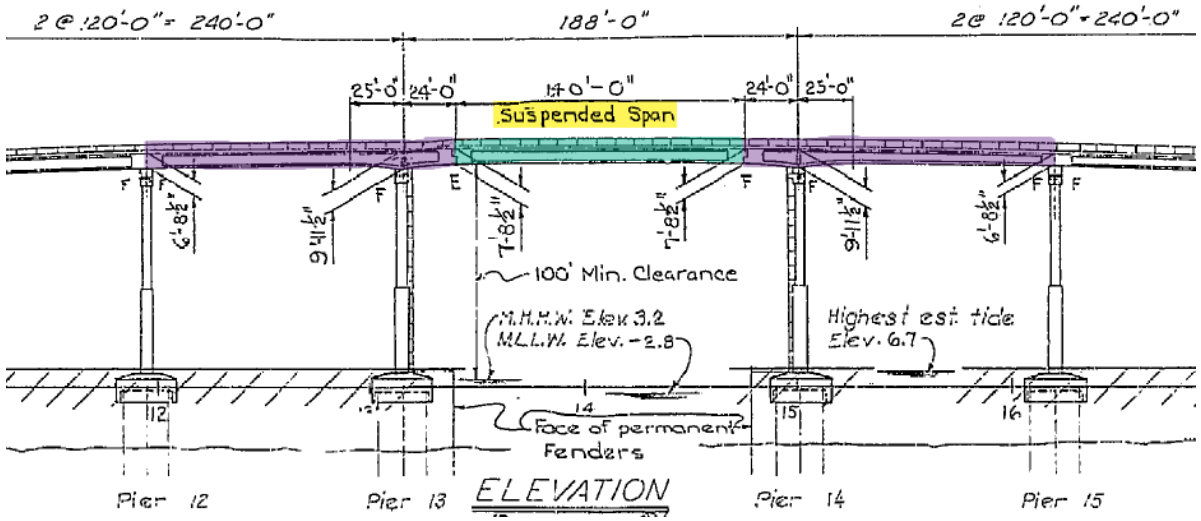


Tendon profile	Start span	Start distance into start span (ft)	End span	End distance from end span (ft)	Stage
PT Sp1 To Sp2 Hinge (Profile 1)	1	0	2	164	Non-composite (Stage 1)
PT Sp1 To Sp2 Hinge (Profile 2)	1	0	2	164	Non-composite (Stage 1)
PT Sp2 Drop-In	2	24	2	24	Non-composite (Stage 1)
PT Sp2 Hinge To Sp3 (Profile 1)	2	164	3	0	Non-composite (Stage 1)
PT Sp2 Hinge To Sp3 (Profile 2)	2	164	3	0	Non-composite (Stage 1)



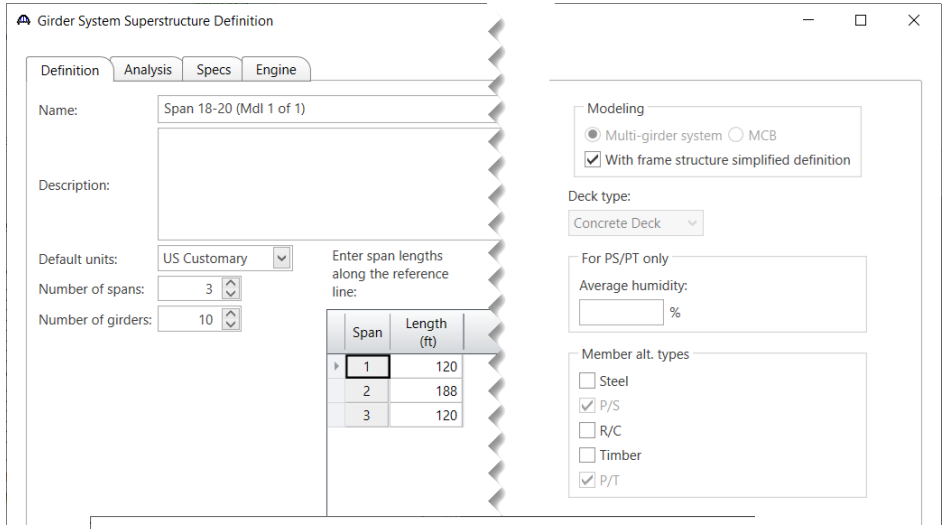
EXAMPLE 1: CANTILEVERED PSI GIRDERS AND SUSPENDED SPAN

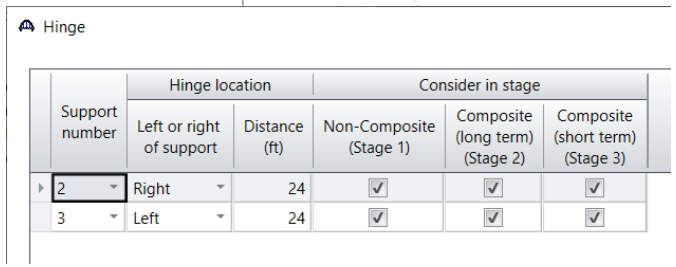




Structural Model:

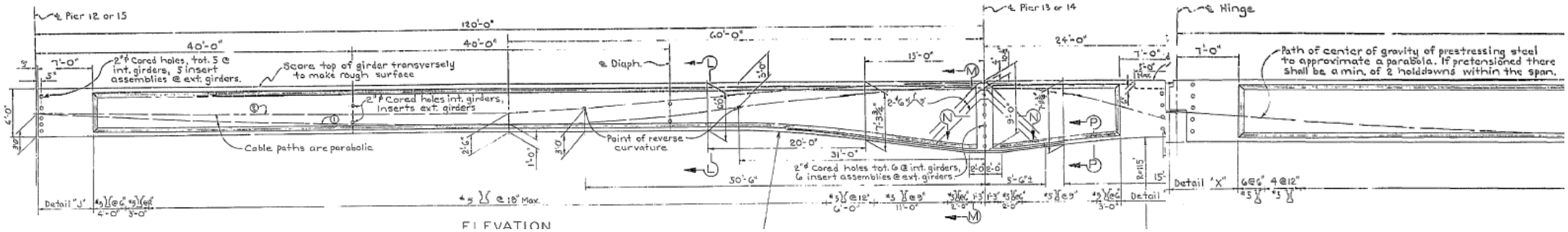
- 3-Span continuous Girder System with framed bent
- ACM with normal hinges within middle span.

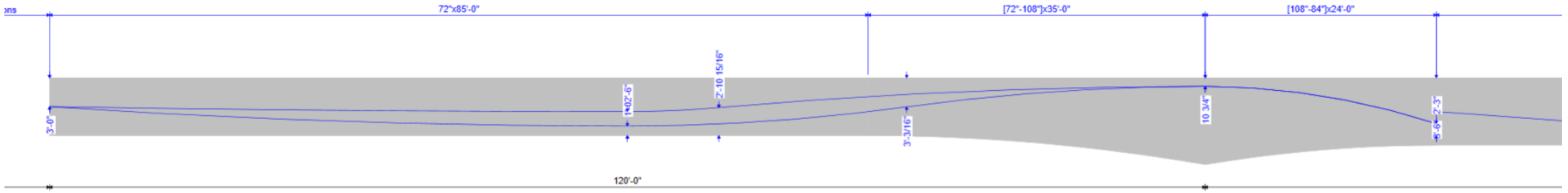




EXAMPLE 1: CANTILEVERED PSI GIRDERS AND SUSPENDED SPAN

Prestressing:



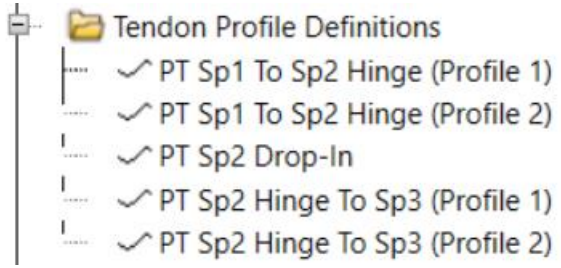


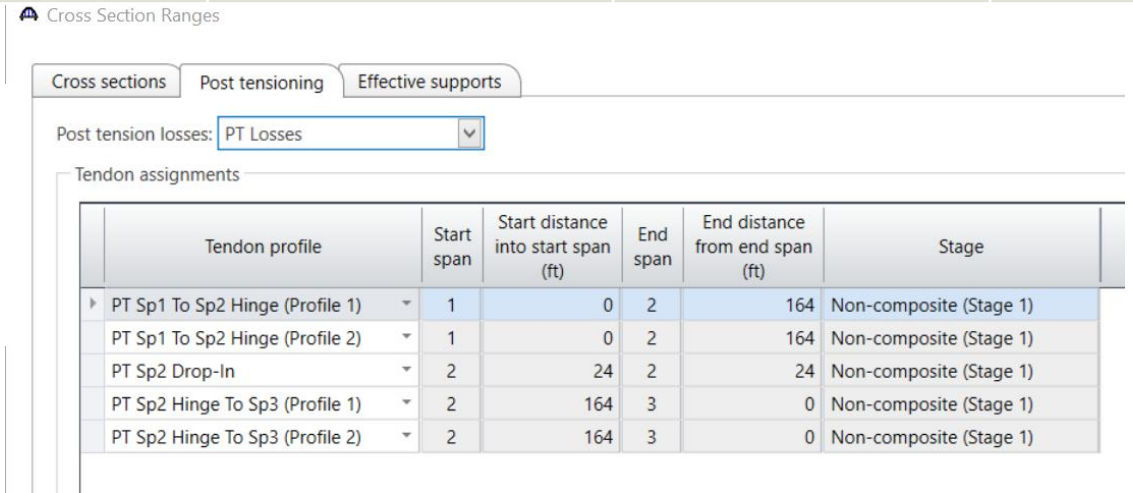
Stressing & Placing Sequence of Operations

1. Stress girder with Prestress Force ①. Non-composite (Stage 1) tensioning **Pre or Post tensioning**
2. Erect Span 12, 14 & 13 girders.
3. Stress girder with Prestress Force ②. Non-composite (Stage 1) tensioning **Post tensioning**
4. Place Slabs, see "Slab Placing Diagram, Spans 12, 13 & 14".

EXAMPLE 1: CANTILEVERED PSI GIRDERS AND SUSPENDED SPAN

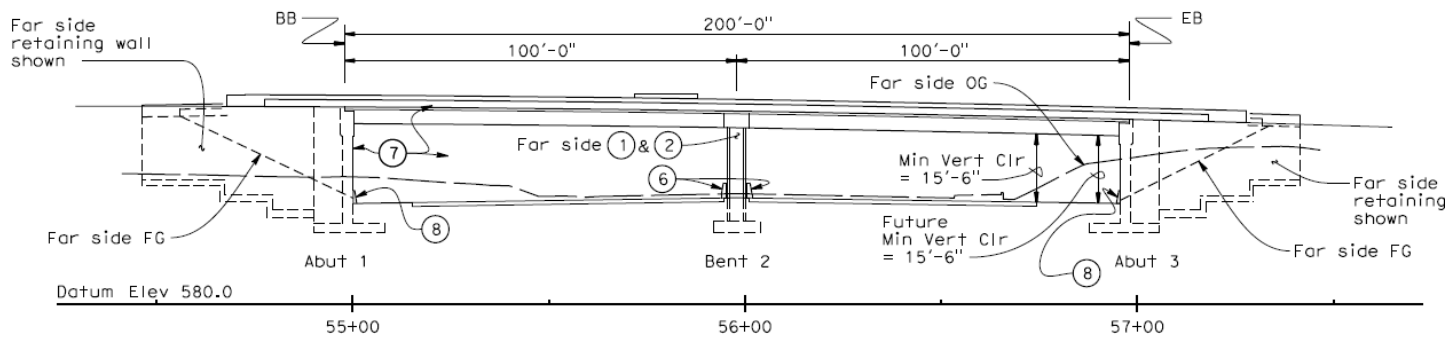
Prestressing	Description	Tensioning Type Per As-Builts	Stage Applied in Model	Limitations
End Spans (Profile 1)	Prestress in girder before erecting	Pre-tension or Post-tension	PT- Stage 1	Losses not accurate if Pre-T
Drop-In	Prestress in girder before erecting	Pre-tension or Post-tension	PT- Stage 1	Losses not accurate if Pre-T
End Spans (Profile 2)	Additional prestress applied to end spans after erecting girders but before deck	Post-tension	PT- Stage 1	None

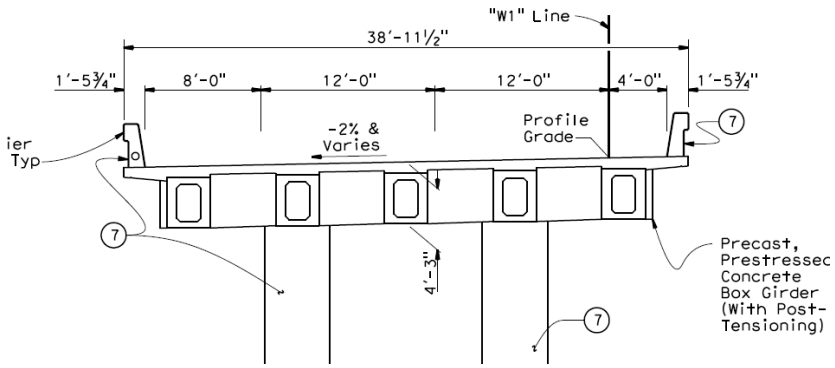


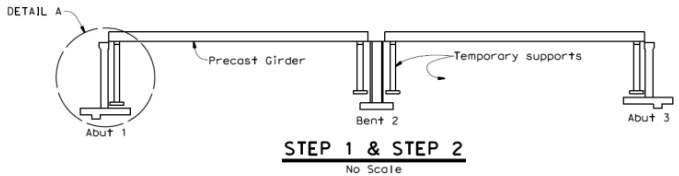


Tendon profile	Start span	Start distance into start span (ft)	End span	End distance from end span (ft)	Stage
PT Sp1 To Sp2 Hinge (Profile 1)	1	0	2	164	Non-composite (Stage 1)
PT Sp1 To Sp2 Hinge (Profile 2)	1	0	2	164	Non-composite (Stage 1)
PT Sp2 Drop-In	2	24	2	24	Non-composite (Stage 1)
PT Sp2 Hinge To Sp3 (Profile 1)	2	164	3	0	Non-composite (Stage 1)
PT Sp2 Hinge To Sp3 (Profile 2)	2	164	3	0	Non-composite (Stage 1)

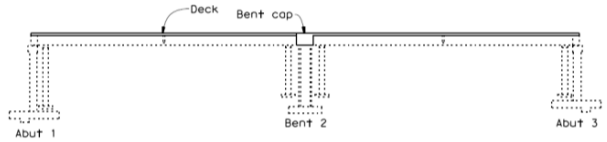
EXAMPLE 2: PS BOX, ONE STAGE PT SPLICE







STEP 1 & STEP 2
No Scale



STEP 4
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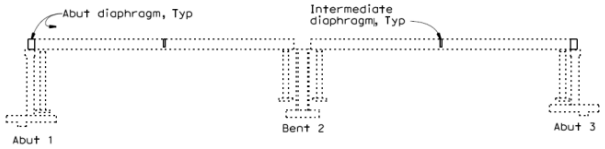

STEP 3
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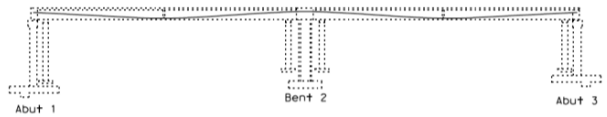


STEP 5 & STEP 6
No Scale

BRIDGE CONSTRUCTION SEQUENCE

Step 1. Construct abutments, bent footings and columns.

Step 2. Erect precast girders on temporary supports. Temporary supports are to be located within 2'-0" of precast girder ends. Maximum loading per bent footing shall be 310 kips per span. Maximum loading per abutment footing shall be 11 kips per linear foot.

Step 3. Construct abutment and intermediate diaphragms.

Step 4. Construct deck in span 1. Starting at Abutment 3, construct deck in span 2 and bent cap last.

Step 5. Complete longitudinal prestressing (post-tensioning). Longitudinal prestressing (post-tensioning) shall not be permitted sooner than 28 days after the last concrete has been placed.

Step 6. Remove temporary supports. Install Type 736 Mod barrier. Barrier shall not be placed prior to post-tensioning.

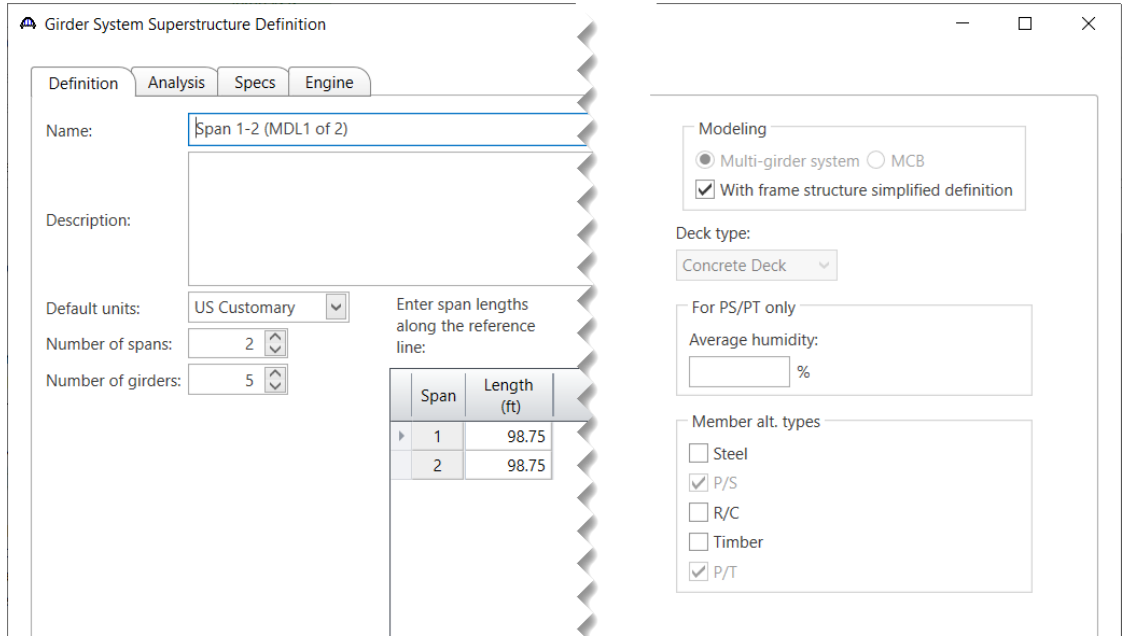
LEGEND:

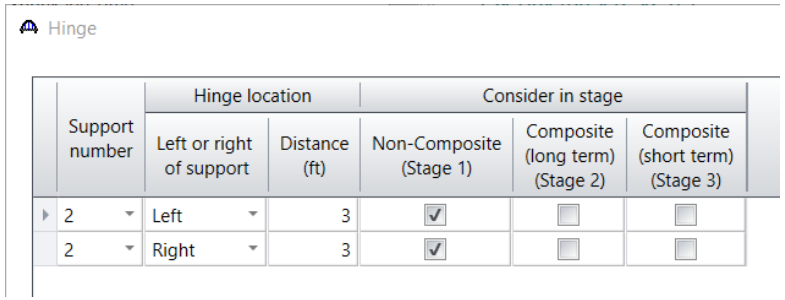
..... Indicates previously completed steps

EXAMPLE 2: PS BOX, ONE STAGE PT SPLICE

Structural Model:

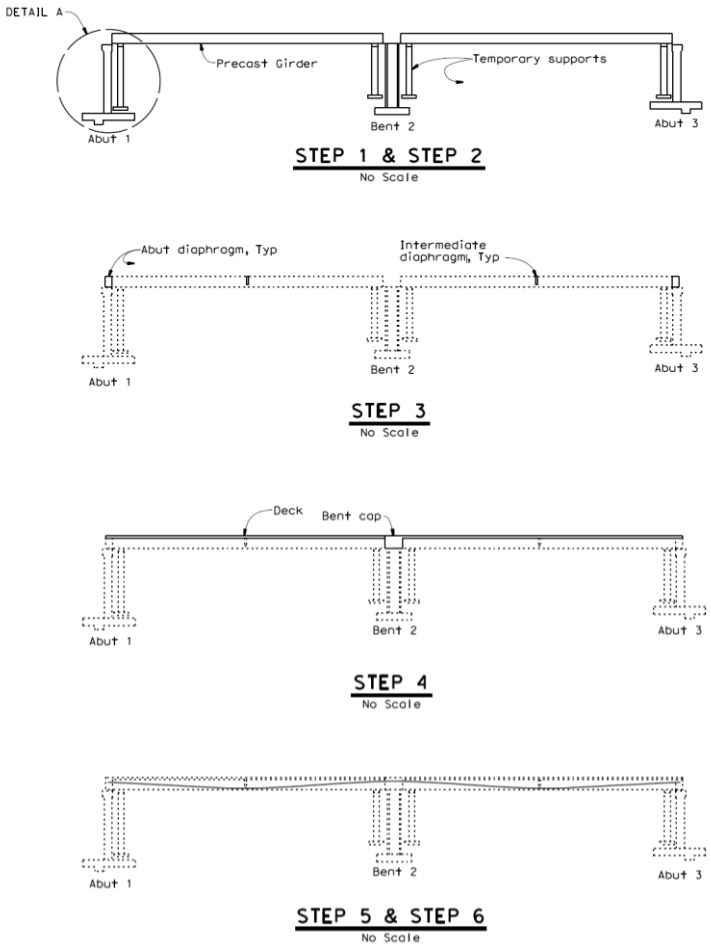
- 2-Span continuous Girder System with framed Bent connection
- ACM with Stage 1 only hinges at temp supports





EXAMPLE 2: PS BOX, ONE STAGE PT SPLICE

Prestressing:



BRIDGE CONSTRUCTION SEQUENCE

Step 1. Construct abutments, bent footings and columns.

Step 2. Erect precast girders on temporary supports. Temporary supports are to be located within 2'-0" of precast girder ends. Maximum loading per bent footing shall be 310 kips per span. Maximum loading per abutment footing shall be 11 kips per linear foot.

Step 3. Construct abutment and intermediate diaphragms.

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Step 5. Complete longitudinal prestressing (post-tensioning). Longitudinal prestressing (post-tensioning) shall not be permitted sooner than 28 days after the last concrete has been placed.

Step 6. Remove temporary supports. Install Type 736 Mod barrier. Barrier shall not be placed prior to post-tensioning.

LEGEND:

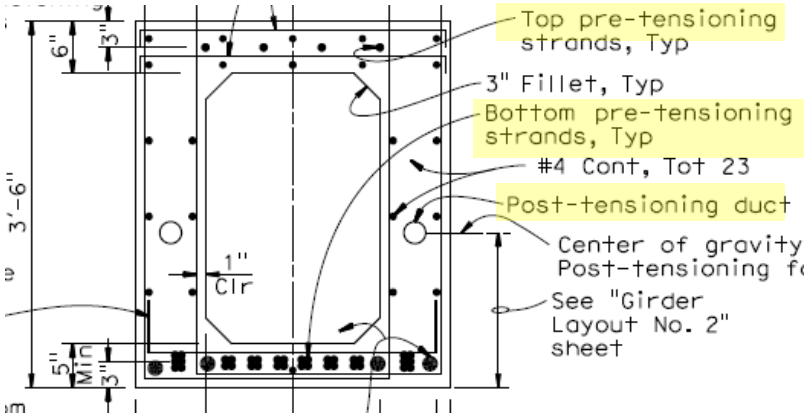
..... Indicates previously completed steps

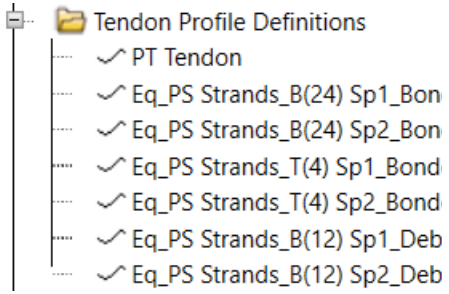
Pre-tensioning
Non-Composite (Stage 1) Tensioning

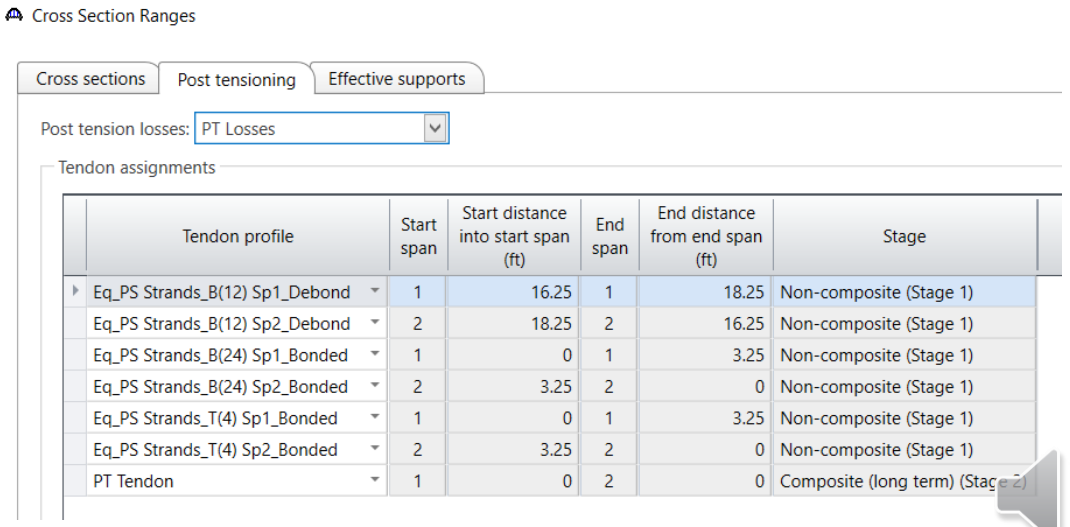
Post-tensioning
Composite (Stage 2) tensioning

EXAMPLE 2: PS BOX, ONE STAGE PT SPLICE

Prestressing	Description	Tensioning Type Per As-Builts	Stage Applied in Model	Limitations
Precast girders	Prestress in girder before erecting	Pre-tension	PT- Stage 1	Losses not accurate
Post Tension	Additional prestress applied after erecting girders and placing deck	Post-tension	PT- Stage 2	None



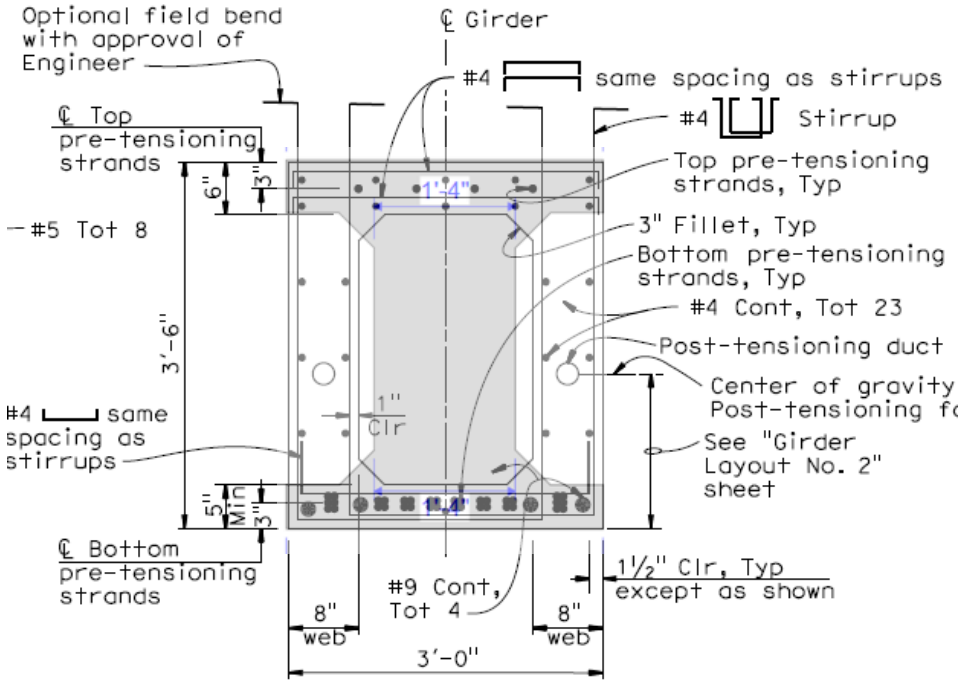


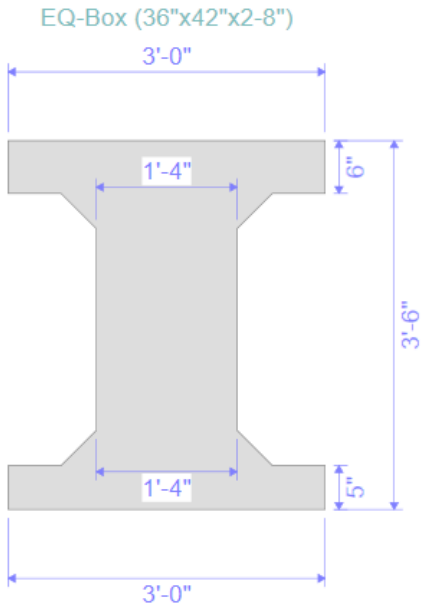


Tendon profile	Start span	Start distance into start span (ft)	End span	End distance from end span (ft)	Stage
Eq_PS Strands_B(12) Sp1_Debond	1	16.25	1	18.25	Non-composite (Stage 1)
Eq_PS Strands_B(12) Sp2_Debond	2	18.25	2	16.25	Non-composite (Stage 1)
Eq_PS Strands_B(24) Sp1_Bonded	1	0	1	3.25	Non-composite (Stage 1)
Eq_PS Strands_B(24) Sp2_Bonded	2	3.25	2	0	Non-composite (Stage 1)
Eq_PS Strands_T(4) Sp1_Bonded	1	0	1	3.25	Non-composite (Stage 1)
Eq_PS Strands_T(4) Sp2_Bonded	2	3.25	2	0	Non-composite (Stage 1)
PT Tendon	1	0	2	0	Composite (long term) (Stage 2)

EXAMPLE 2: PS BOX, ONE STAGE PT SPLICE

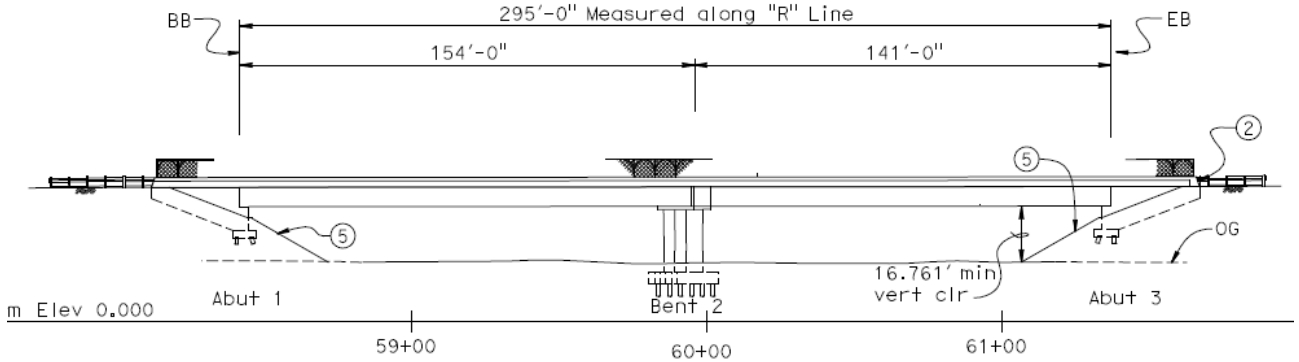
Cross Section:

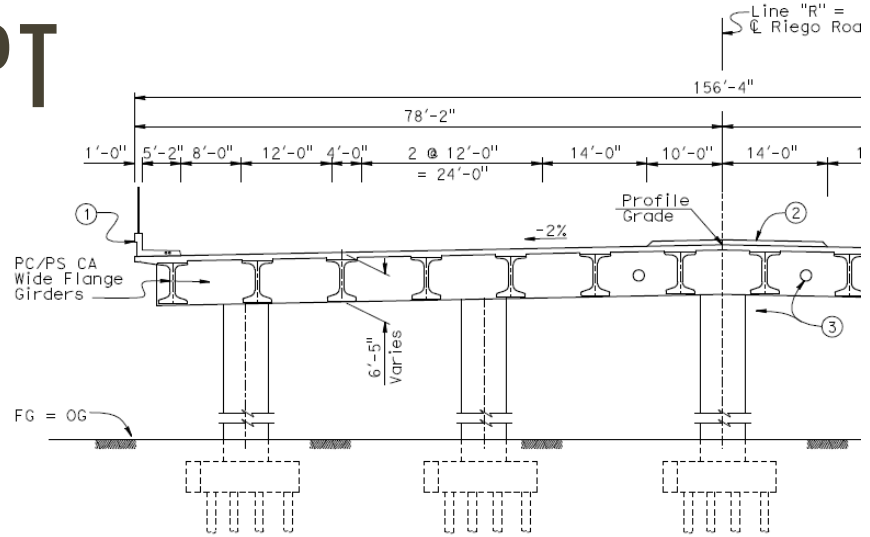


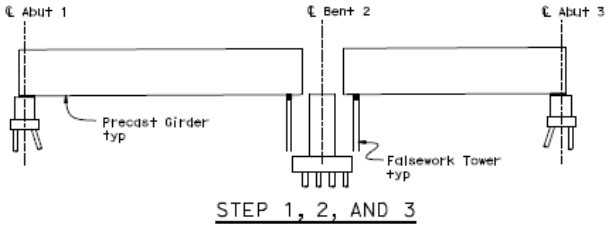


LLDF must be input manually since PS precast box section not directly supported by ACM

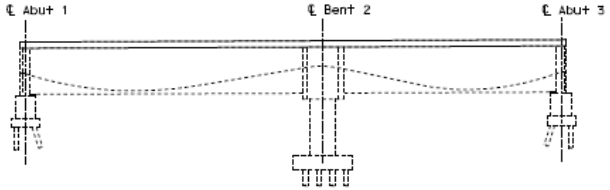
EXAMPLE 3: SPLICED PSI, 2 STAGE PT



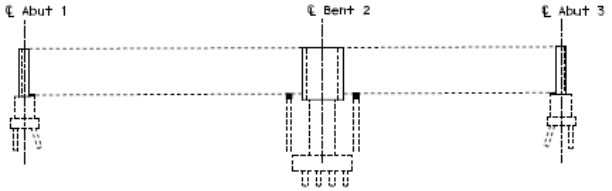




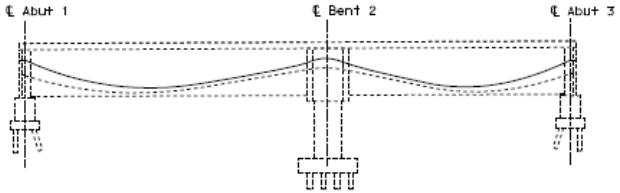
STEP 1, 2, AND 3



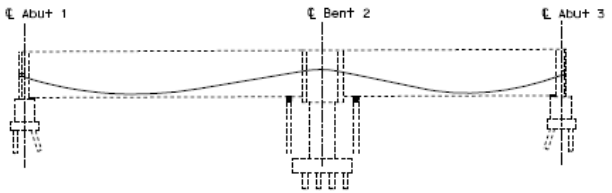
STEP 6 AND STEP 7



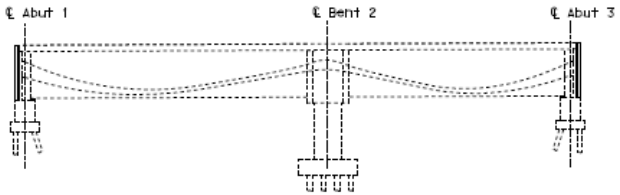
STEP 4



STEP 8



STEP 5



STEP 9

BRIDGE CONSTRUCTION SEQUENCE

Step 1: Construct abutments, bent footings, and columns.

Step 2: Erect Falsework Towers.

Step 3: Erect precast prestressing girders on Abutment and falsework towers.

Step 4: Construct cast-in-place end diaphragms and bent cap. Allow cast-in-place end diaphragms and bent cap concrete to reach a minimum strength of 3500 psi.

Step 5: Complete Stage 1 prestressing (post-tensioning).

Step 6: Remove Falsework Towers.

Step 7: Form and pour deck concrete.

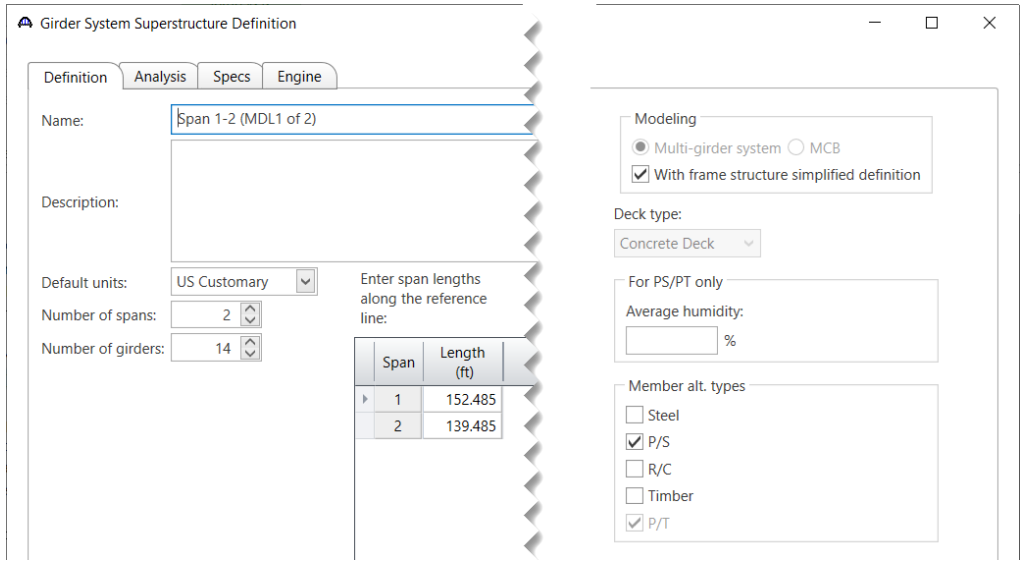
Step 8: Complete Stage 2 prestressing (post-tensioning). Stage 2 prestressing shall not be permitted less than 10 days after deck concrete has been placed and the deck concrete compressibe strength at time of stressing has achieved the minimum specified f'_{ci} (3500 psi).

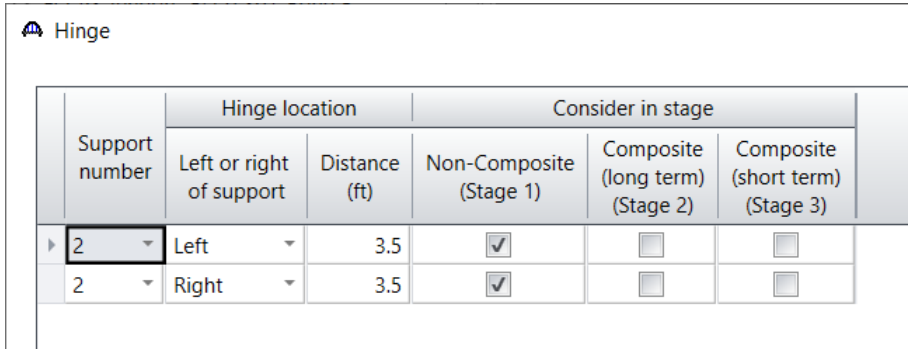
Step 9: Complete prestress blockouts, construct backwalls at abutments, approach slab, barrier rails, and raised median.

EXAMPLE 3: SPLICED PSI, 2 STAGE PT

Structural Model:

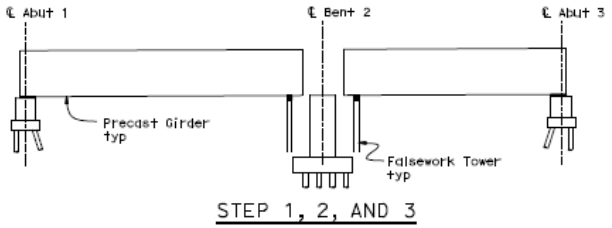
- 2-Span continuous Girder System with Framed bent
- ACM with Stage 1 only hinges at temp supports



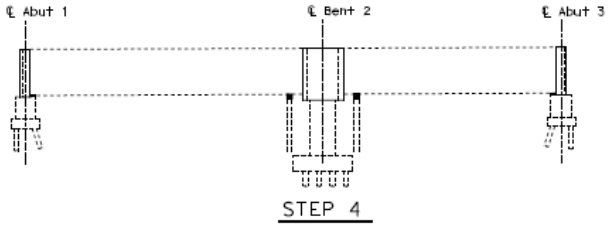


EXAMPLE 3: SPLICED PSI, 2 STAGE PT

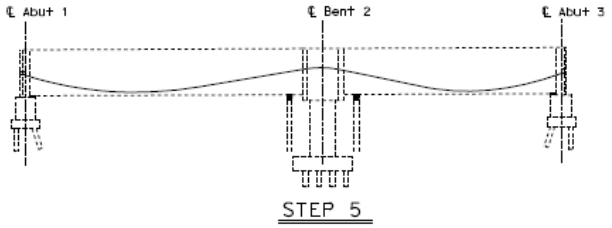
Prestressing:



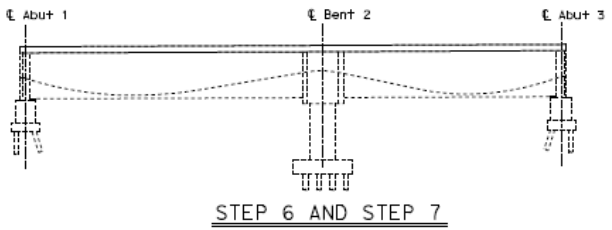
STEP 1, 2, AND 3



STEP 4



STEP 5



STEP 6 AND STEP 7

BRIDGE CONSTRUCTION SEQUENCE

Step 1: Construct abutments, bent footings, and columns.

Step 2: Erect Falsework Towers.

Step 3: Erect precast prestressing girders on Abutment and falsework towers.

Pre-tensioning
Non-composite (Stage 1) tensioning

Step 4: Construct cast-in-place end diaphragms and bent cap. Allow cast-in-place end diaphragms and bent cap concrete to reach a minimum strength of 3500 psi.

Step 5: Complete Stage 1 prestressing (post-tensioning).

Post-tensioning
Non-Composite (Stage 1) tensioning

Step 6: Remove Falsework Towers.

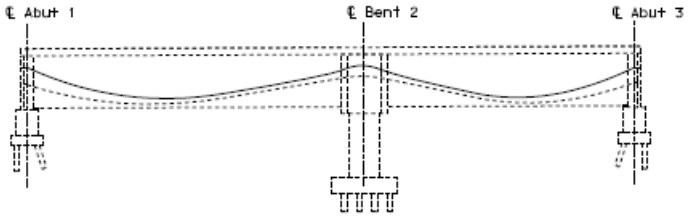
Step 7: Form and pour deck concrete.

Step 8: Complete Stage 2 prestressing (post-tensioning). Stage 2 prestressing shall not be permitted less than 10 days after deck concrete has been placed and the deck concrete compressibe strength at time of stressing has achieved the minimum specified f'_{ci} (3500 psi).

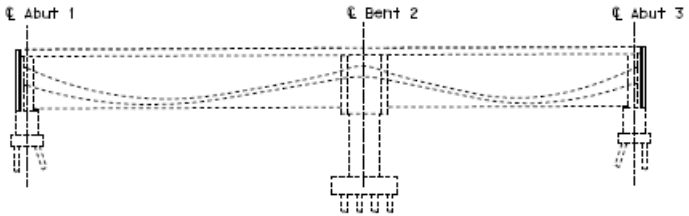
Post-tensioning
Composite (Stage 2) tensioning

Step 9: Complete prestress blockouts, construct backwalls at abutments, approach slab, barrier rails, and raised median.

Step 9: Complete prestress blockouts, construct backwalls at abutments, approach slab, barrier rails, and raised median.



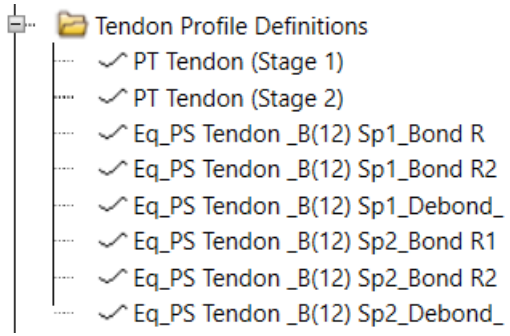
STEP 8

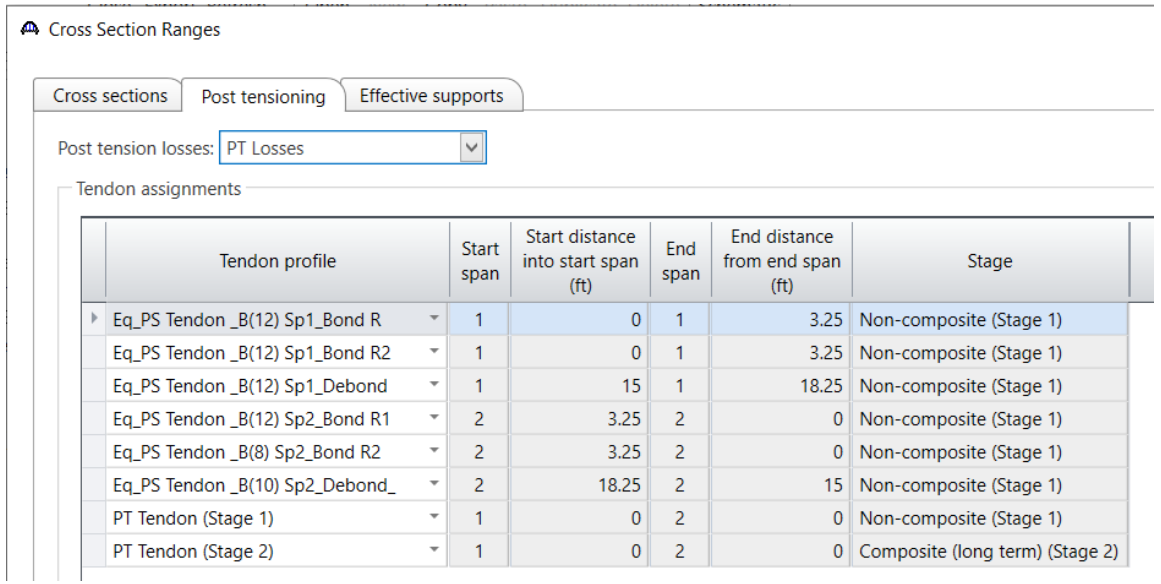


STEP 9

EXAMPLE 3: SPLICED PSI, 2 STAGE PT

Prestressing	Description	Tensioning Type Per As-Builts	Stage Applied in Model	Limitations
Precast girders	Prestress in girders before erecting	Pre-tension	PT- Stage 1	Losses not accurate
Post Tension 1	Prestress applied after erecting girders but before deck	Post-tension	PT- Stage 1	None
Post Tension 2	Prestress applied after placing deck	Post-tension	PT- Stage 2	None

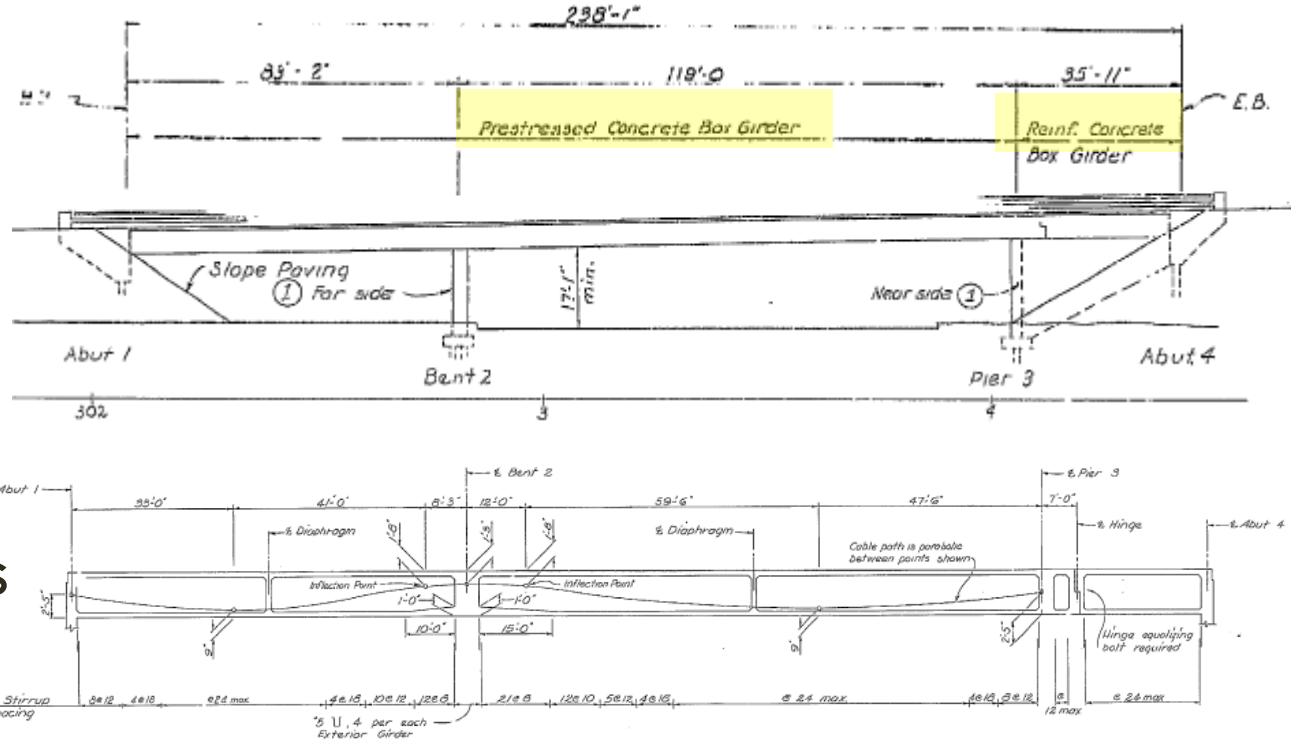




Tendon profile	Start span	Start distance into start span (ft)	End span	End distance from end span (ft)	Stage
Eq_PS Tendon _B(12) Sp1_Bond R	1	0	1	3.25	Non-composite (Stage 1)
Eq_PS Tendon _B(12) Sp1_Bond R2	1	0	1	3.25	Non-composite (Stage 1)
Eq_PS Tendon _B(12) Sp1_Debond	1	15	1	18.25	Non-composite (Stage 1)
Eq_PS Tendon _B(12) Sp2_Bond R1	2	3.25	2	0	Non-composite (Stage 1)
Eq_PS Tendon _B(8) Sp2_Bond R2	2	3.25	2	0	Non-composite (Stage 1)
Eq_PS Tendon _B(10) Sp2_Debond_	2	18.25	2	15	Non-composite (Stage 1)
PT Tendon (Stage 1)	1	0	2	0	Non-composite (Stage 1)
PT Tendon (Stage 2)	1	0	2	0	Composite (long term) (Stage 2)

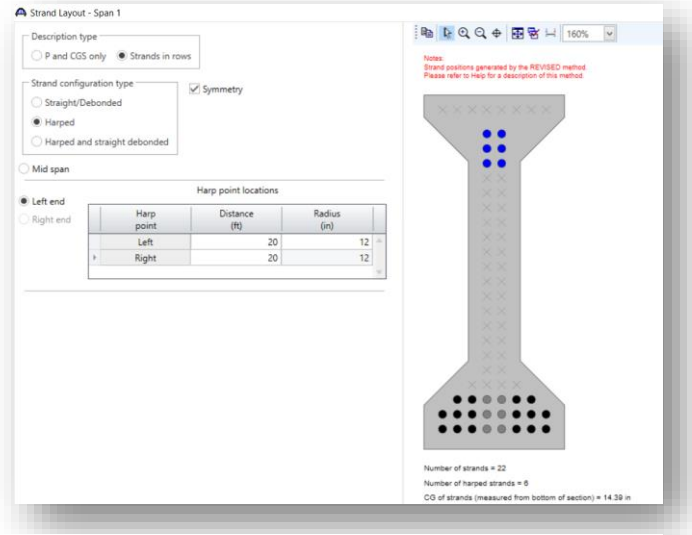
OTHER EXAMPLES

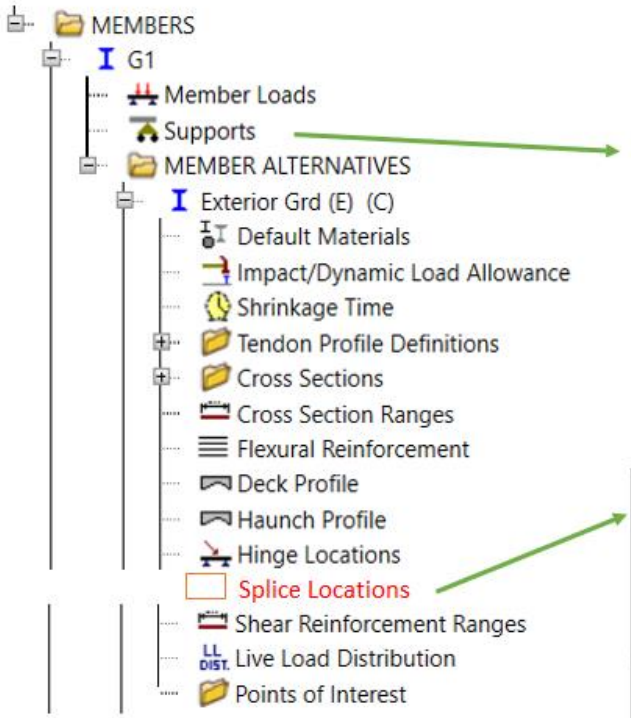
- CIP MCB
  - with different tendon paths in each girder
  - Only portion of bridge post-tensioned
- Overlapping tendons, stacked tendons
- T girder (RC and/or PT)
- Cont. bridge where girder type changes (e.g. Precast I main spans, T girder end spans)
- Use ACM when structure has features that are outside the capability of other types

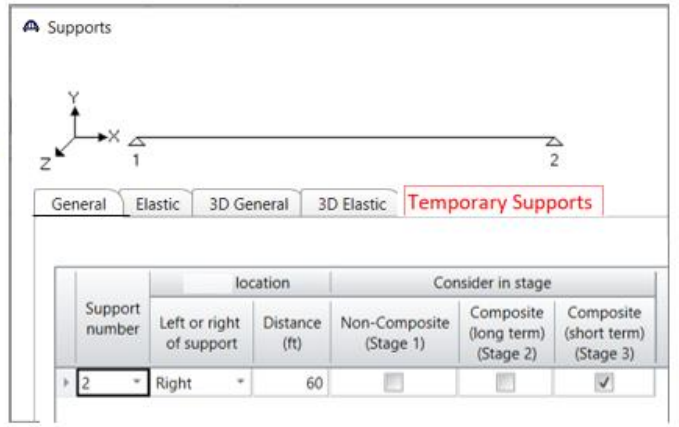


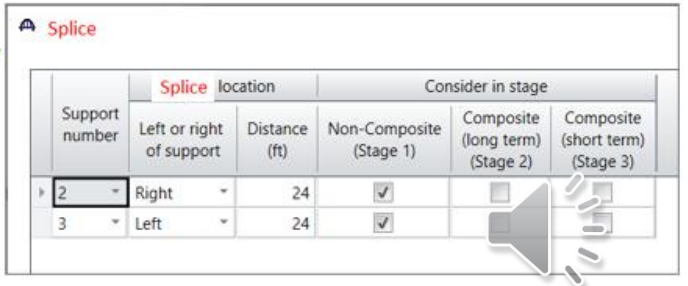
POSSIBLE IMPROVEMENTS FOR ACM 2.0

- Add capability to model Pre-tensioning directly:
  - Strand patterns & debonding
  - Harped profile
- Additional Cross Section Shapes?
- Spliced girders:
  - Splice Locations
    - Vertical support and release for moment
  - Additional intermediate stages (Stage 1a, 1b, 1c, 2a, 2b, etc)
- Add Option for Temporary Support

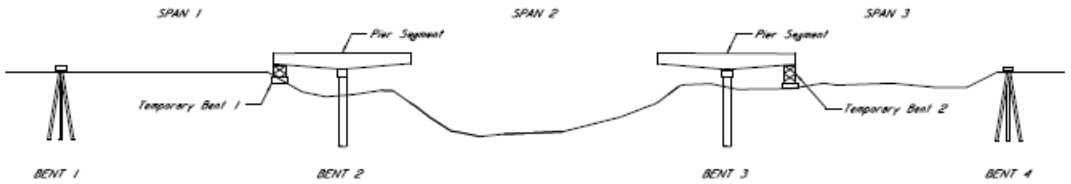






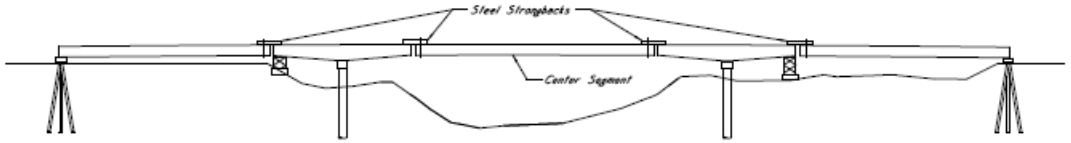


ACM 2.0 EXAMPLE 1

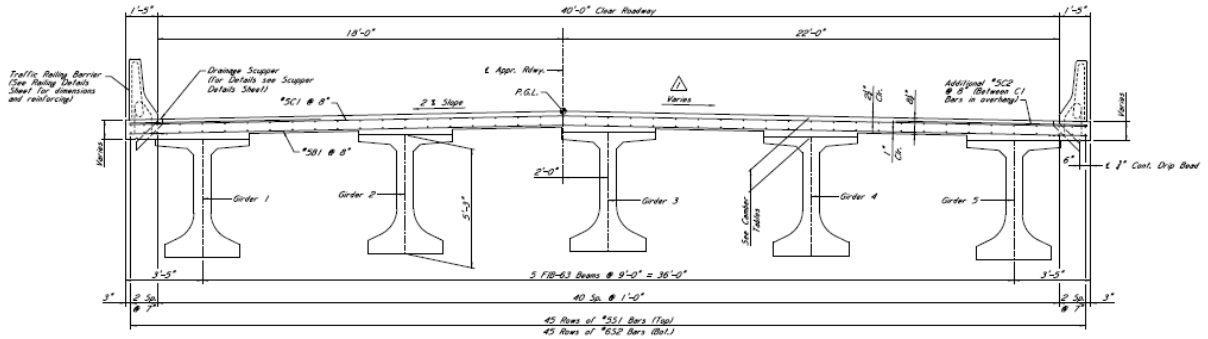


STAGE 1

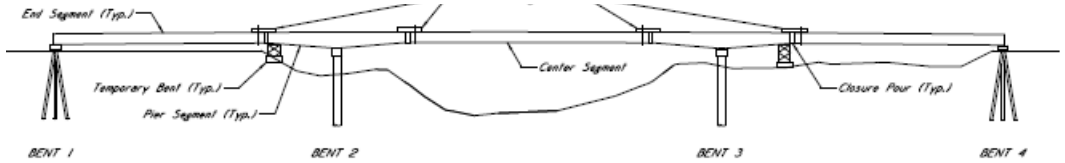
STAGE 2



STAGE 3



DECK SECTION - END AND CENTER SEGMENTS
(Looking Upstation)

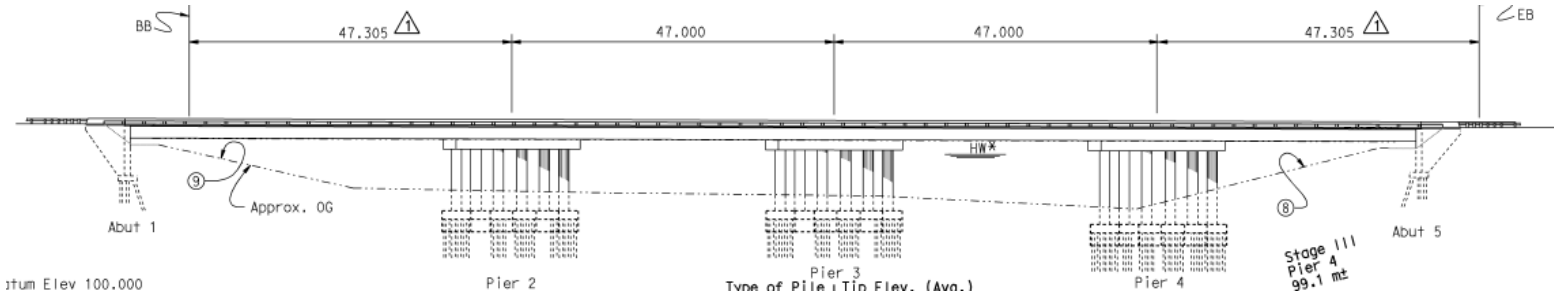


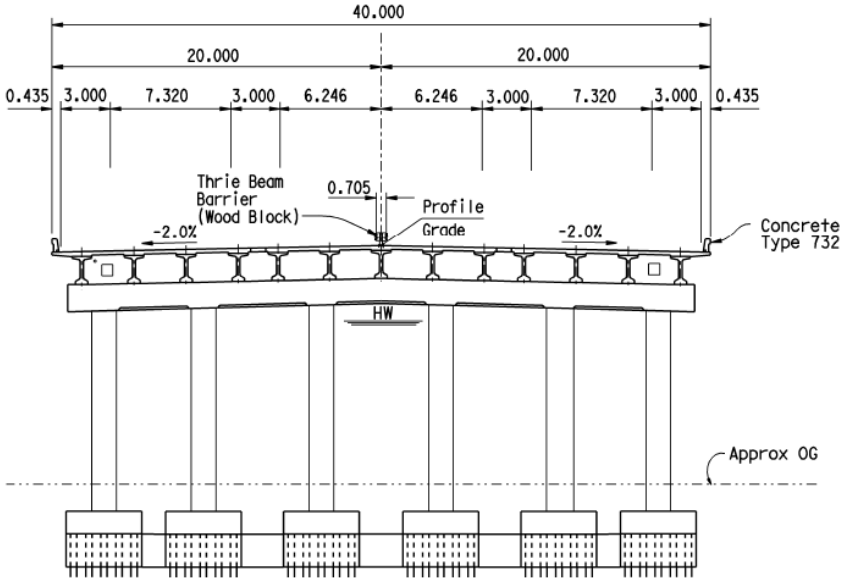
STAGE 4

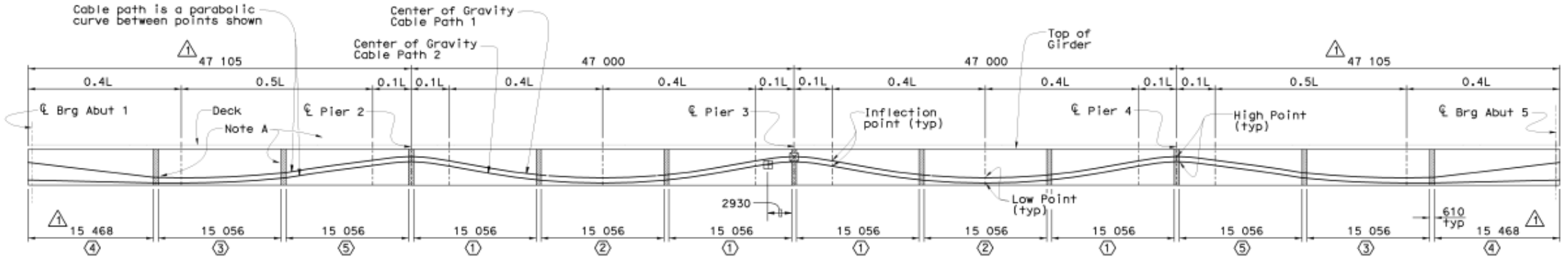
STAGE 5

STAGE 6

ACM 2.0 EXAMPLE 2







LONGITUDINAL SECTION

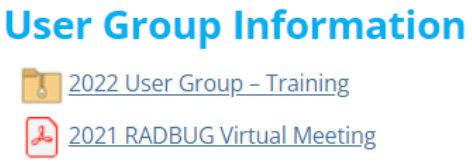
No scale

ADDITIONAL RESOURCES

AASHTOWare Bridge website, Training page

https://www.aashtowarebridge.com/bridge-rating-and-design/training/

- 2021 RADBUG Presentation “Advanced (Post-Tensioned) Concrete Beam”



- “Advanced Concrete” Tutorials

THANK YOU!

Igor Chernioglo, P.E.
igor.chernioglo@dot.ca.gov