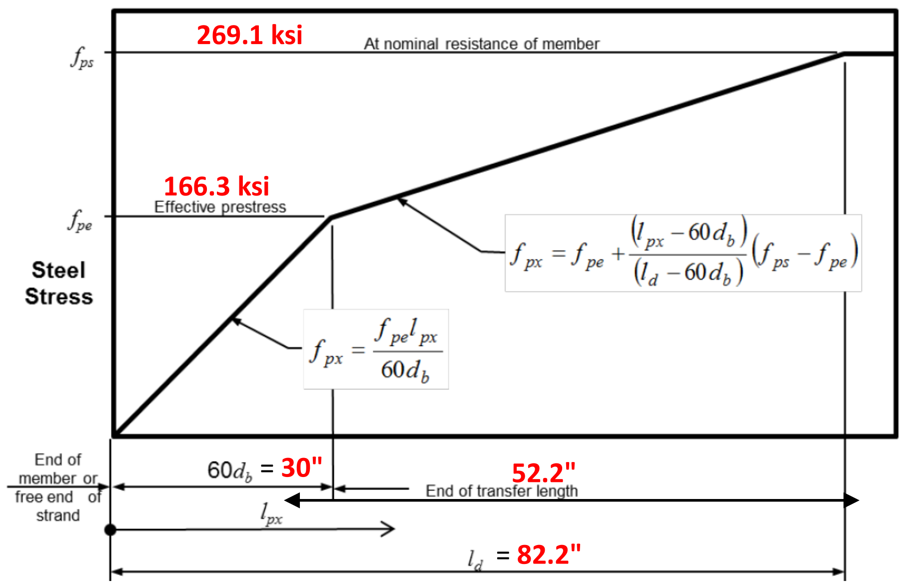
The considered beam includes a total of 9×1/2”-diameter strands (two of them are debonded at the two ends for a length of 18.7”). For the LFR approach, the moment capacity computed by LEAP Bridge at H/2 = 21.5” is very low (only 30% of the moment capacity calculated by LEAP Bridge for the LRFR approach) so that this location governs the rating. An investigation of the LEAP Bridge outputs illustrates that the considered prestressing area for the LFR approach is much less than that for the LRFR approach. We have performed hand calculations to verify the considered prestressing area by LEAP Bridge at H/2 for the two approaches. Our calculations show that (1) the development length and transfer length are not significantly different for the LFR and LRFR approaches; (2) the considered prestressing area by LEAP Bridge for the LRFR matches our hand calculation but for the LFR is much less than our hand calculation result. The underestimation of the prestressing area in LRF approach will result in an underestimation of the moment capacity. A summary of our calculation is provided below:

LRFR:

Based on LEAP Bridge outputs, which are included in Pages 2 and 3 of this document, for LRFR: f_{ps}=269.1 ksi and f_{pe}=166.3 ksi. Using these values and the equations provided in AASHTO LRFD the development length and transfer length are 82" and 30", respectively:



Total area of the 9 strands is 1.37 in^2. Considering the debonded strands and the development length, our calculations show that at H/2, the total effective area for the strands, A'_{ps}, is 0.491 in^2 which is close to the LEAP Bridge result (0.505 in^2):

There are seven strands with full bonding and two debonded strands at $H/2 = 21.5”$

For 7 strands with full bonding: $f_{px} = \left(\frac{21.5"}{30"}\right)(166.3) = 119\ ksi$

For 2 debonded strands: $f_{px} = \left(\frac{21.5" - 18.69"}{30"}\right)(166.3) = 15.58\ ksi$

The effective prestressing area can be determined using this equation:

$$A'_{ps} = \left(\frac{f_{px}}{f_{ps}}\right) A_{ps}$$

$$A'_{ps} = \left(\frac{119}{269.1}\right)(7)(0.153) + \left(\frac{15.58}{269.1}\right)(2)(0.153) = 0.491\ in^2$$

	Elastic Gains	Gains		Adjustment	
due	to Precast Loads	-2.93	ksi	0.12	ksi
due	to Composite Loads	-0.31	ksi	0.01	ksi
due	to Live Loads	-4.87	ksi	0.25	ksi

LRFR Approach

Time Dependent Losses (Approximate Method (Art.5.9.3.3))

		Initial		Final		
Steel relaxation	0.00	ksi		2.40	ksi	(Eq 5.9.3.3-1)
Concrete shrinkage	0.00	ksi		11.40	ksi	(Eq 5.9.3.3-1)
Concrete creep	0.00	ksi		6.64	ksi	(Eq 5.9.3.3-1)
Sub-total	8.14	ksi	(4.35 %)	12.72	ksi	(6.79 %)
Total Prestress Losses				20.86	ksi	(11.14 %)

Prestressing Stress Limit Check (Table 5.9.3.1)
initial fpi = 187.2 ksi < 0.75 fpu, OK
initial fpe = 166.3 ksi < 0.80 fpy, OK

ULTIMATE MOMENT

ULTIMATE - Span : 1, Beam : 10, STRENGTH I
(Mr-prvd computed by AASHTO equations, Art. 5.7.3.2/5.7.3.3)

Location (ft) / Mu k.ft	dp in	Aps in2	fps ksi	c in	a in	Mr-prvd k.ft	eps_t	Phi	Mcr k.ft	min Mr k.ft	Crkg Ratio	Mu-p/r Ratio
Transfer	2.44											
360.0	38.3	0.726	268.7	0.6	0.54	618.8	0.182T	1.00	-	-	-	-
H/2	1.79											
270.8	38.2	0.505	269.1	0.5	0.37	430.6	0.262T	1.00	-	-	-	-
0.1L	3.47											
492.8	39.3	0.870	268.5	0.8	0.64	759.0	0.151T	1.00	-	-	-	-
0.2L	7.00											
861.7	38.4	1.148	268.0	1.0	0.85	973.2	0.114T	1.00	-	-	-	-
0.3L	10.53											
1096.6	38.5	1.343	267.6	1.2	0.99	1137.6	0.097T	1.00	1057.8	1057.8	1.08	-
0.4L	14.05											
1222.7	38.6	1.377	267.6	1.2	1.02	1169.3*	0.095T	1.00	1033.3	1033.3	1.13	-
0.5L	17.58											
1251.6	38.6	1.377	267.6	1.2	1.02	1169.3*	0.095T	1.00	1023.0	1023.0	1.14	-
0.6L	21.11											
1223.6	38.6	1.377	267.6	1.2	1.02	1169.3*	0.095T	1.00	1032.7	1032.7	1.13	-
0.7L	24.64											
1097.3	38.5	1.343	267.6	1.2	0.99	1137.6	0.097T	1.00	1057.3	1057.3	1.08	-
0.8L	28.17											
862.2	38.4	1.148	268.0	1.0	0.85	973.2	0.114T	1.00	-	-	-	-
0.9L	31.70											
493.0	39.3	0.870	268.5	0.8	0.64	759.0	0.151T	1.00	-	-	-	-
H/2	33.38											
271.0	38.2	0.505	269.1	0.5	0.37	430.6	0.262T	1.00	-	-	-	-
Transfer	32.73											
360.2	38.3	0.726	268.7	0.6	0.54	618.8	0.182T	1.00	-	-	-	-

Legend: C = Compression-Controlled (0 < eps_t < 0.0020)
I = In-Transition (0.0020 <= eps_t < 0.0050)
T = Tension-Controlled (eps_t <= 0 or eps_t >= 0.0050)

Note : fr used for calculating Mcr is user input 0.24 x sqrt(fc) x lambda

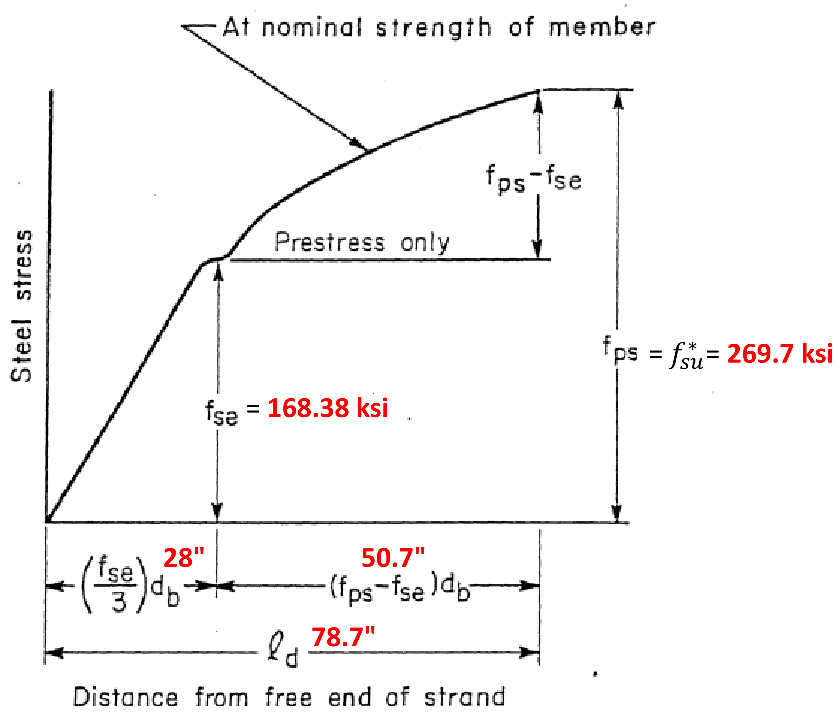
Consider Bottom Tension Steel Contribution : NO

LFR:

Based on LEAP Bridge outputs, which are included in Pages 6 and 7 of this document, for LFR: f_{ps}=269.7 ksi and f_{pe}=168.38 ksi. Using these values and the equations provided in AASHTO Standard for Load Factor Design, the development length and transfer length are 78.7" and 28", respectively, which are close to those computed based on AASHTO LRFD on Page 1.

$$l_d = \left(f_{su}^* - \frac{2}{3} f_{se}\right) d_b$$

$$l_d = \left(269.7 - \frac{2}{3}(168.38)\right)(0.5) = 78.7"$$



Total area of the 9 strands is 1.37 in^2. Considering the debonded strands and the development length, our calculations show that at H/2, the total effective area for the strands, A'_{ps}, is 0.53 in^2 which is significantly greater than the LEAP Bridge result (0.21 in^2):

There are seven strands with full bonding and two debonded strands at $H/2 = 21.5''$

For 7 strands with full bonding: $f_{px} = \left(\frac{21.5"}{28"}\right)(168.38) = 129.29\ ksi$

For 2 debonded strands: $f_{px} = \left(\frac{21.5" - 18.69"}{28"}\right)(168.38) = 16.90\ ksi$

The effective prestressing area can be determined using this equation:

$$A'_{ps} = \left(\frac{f_{px}}{f_{ps}}\right) A_{ps}$$

$$A'_{ps} = \left(\frac{129.29}{269.7}\right)(7)(0.153) + \left(\frac{16.90}{269.7}\right)(2)(0.153) = 0.53\ in^2$$

Bentley		Sheet #	6
		Job #	

Program:	LEAP® Bridge Concrete CONNECT Edition	EAC Consulting Inc		Designed	PM
Module:	Precast/Prestressed Girder	Copyright © Bentley Systems, Inc. 2020		Date	Feb/22/2023
Version:	20.00.00.58	www.bentley.com	Phone: 1-800-778-4277	Checked	HA
File Name:	**Span 3 - LR for EV.lbcx**			Date	Feb/22/2023

			Release			**Final**	**(Art. 9.16.2)**
Steel relaxation	*	1265.30	psi	CRs (Eq 9-10A)	4272.52	psi	
Elastic Shortening	**	0.00	psi	ES (Eq 9-6)	0.00	psi	(Fcir= 958.53 psi)
Concrete shrinkage		0.00	psi	SH (Eq 9-4)	5750.00	psi	
Concrete creep		0.00	psi	CRc (Eq 9-9)	8799.65	psi	(Fcds=-386.11 psi)
Total		1265.30	psi	(0.68 %)	18822.16	psi	(10.05 %)

LFR Approach

* Steel relax. before release - Ref: PCI Journal Vol. 20, No. 4, Jul-Aug 1975
** Transformed section properties option has been selected, therefore ES losses have not been calculated explicitly but included as a part of stress calculations. Please see theory section for complete explanation.

Initial P/S = 187.2 ksi
Loss = 18.8 ksi
F_{pe} = 187.2-18.2 = 168.38 ksi

Bentley		Sheet #	7
		Job #	
Program: LEAP® Bridge Concrete CONNECT Edition	EAC Consulting Inc	Designed	PM
Module: Precast/Prestressed Girder	Copyright © Bentley Systems, Inc. 2020	Date	Feb/22/2023
Version: 20.00.00.58	www.bentley.com Phone: 1-800-778-4277	Checked	HA
File Name: **Span 3 - LR for EV.lbcx**		Date	Feb/22/2023

ULTIMATE MOMENT

ULTIMATE - Span : 1, Beam : 10, FACTORED 1
(Mu-prvd computed by AASHTO equations, Art. 9.17/9.18)
(f'c_eff, ksi = 4.50; beta1 = 0.825)

Location (ft)	A*s in2	Ycg in	p*(A*s/bd)	f*su ksi	a in	Mu-prvd k.ft	Mu-rqrd k.ft	Mcr k.ft	Crkg Ratio	Mu-p/r Ratio
Transfer	2.02									
	0.241	4.84	0.00007	269.6	0.2	206.3	68.2	812.7	0.254	3.02
H/2	1.79									
	0.210	4.85	0.00006	269.7	0.2	180.0	60.9	736.9	0.244	2.96
0.1L	3.47									
	0.436	4.47	0.00012	269.3	0.3	375.6	112.1	916.6	0.410	3.35
0.2L	7.00									
	0.912	4.53	0.00025	268.6	0.7	778.3	202.2	875.6	0.889	3.85
0.3L	10.53									
	1.297	4.51	0.00036	268.0	1.0	1100.9	267.9	836.8	1.316	-
0.4L	14.05									
	1.377	4.41	0.00038	267.9	1.0	1170.4	309.2	812.3	1.441	-
0.5L	17.58									
	1.377	4.41	0.00038	267.9	1.0	1170.4	326.2	802.0	1.459	-
0.6L	21.11									
	1.377	4.41	0.00038	267.9	1.0	1170.4	310.1	811.7	1.442	-
0.7L	24.64									
	1.297	4.51	0.00036	268.0	1.0	1100.9	268.5	836.4	1.316	-
0.8L	28.17									
	0.912	4.53	0.00025	268.6	0.7	778.3	202.6	875.3	0.889	3.84
0.9L	31.70									
	0.436	4.47	0.00012	269.3	0.3	375.6	112.4	916.4	0.410	3.34
H/2	33.38									
	0.210	4.85	0.00006	269.7	0.2	180.0	61.0	736.8	0.244	2.95
Transfer	33.15									
	0.241	4.84	0.00007	269.6	0.2	206.3	68.4	812.6	0.254	3.02