Bridge No.	999999	**Analysis Method:**	LRFR-LRFD
Location	CR123 over Culvert Ck		
Description	Index 6037 Triple 10x10, 1958		

FDOT Bridge Load Rating Summary Form (Page 1 of 1)

Rating Type	Rating Type	Gross Axle Weight (tons)	Moment/Shear/Service		Dead Load Factor	Live Load Factor	Live Load Distrib. Factor (axles)	Rating Factor	Span No. - Girder No., Interior/Exterior, %Span·L	Pontis RF·Weight (tons)
Level	**Vehicle**	**Weight**	**Member Type**	**Limit**	**DC**	**LL**	**LLDF**	**RF**	**Governing Location**	**RATING**
Inventory	HL93	36	Reinf. Concrete	Strength, Moment	1.25/0.90	1.75	0.000	0.851	Top Slab at 1.40, D.fill = 1.90ft.	30.6
Operating	HL93	36	Reinf. Concrete	Strength, Moment	1.25/0.90	1.35	0.000	1.103	Top Slab at 1.40, D.fill = 1.90ft.	39.7
Permit	FL120	60	Reinf. Concrete	Strength, Moment	1.25/0.90	1.35	0.000	0.883	Top Slab at 1.40, D.fill = 1.90ft.	53.0
Permit Max Span	FL120	60	Reinf. Concrete	Strength, Moment	1.25/0.90	1.35	0.000	0.883	Top Slab at 1.40, D.fill = 1.90ft.	53.0
Legal	SU2	17	Reinf. Concrete	Strength, Moment	1.25/0.90	1.35	0.000	2.145	Top Slab at 1.40, D.fill = 1.90ft.	36.5
	SU3	33	Reinf. Concrete	Strength, Moment	1.25/0.90	1.35	0.000	1.539	Top Slab at 1.40, D.fill = 1.90ft.	50.8
	SU4	35	Reinf. Concrete	Strength, Moment	1.25/0.90	1.35	0.000	1.741	Top Slab at 1.40, D.fill = 1.90ft.	60.9
	C3	28	Reinf. Concrete	Strength, Moment	1.25/0.90	1.35	0.000	2.041	Top Slab at 1.40, D.fill = 1.90ft.	57.2
	C4	36.7	Reinf. Concrete	Strength, Moment	1.25/0.90	1.35	0.000	1.495	Top Slab at 1.40, D.fill = 1.90ft.	54.8
	C5	40	Reinf. Concrete	Strength, Moment	1.25/0.90	1.35	0.000	1.609	Top Slab at 1.40, D.fill = 1.90ft.	64.4
	ST5	40	Reinf. Concrete	Strength, Moment	1.25/0.90	1.35	0.000	1.838	Top Slab at 1.40, D.fill = 1.90ft.	73.5

Original Design Load	H15 or H-15-44		Performed by:	Andrew DeVault	Date: 04/12/16
Rating Type, *Analysis*	LRFR-LRFD		Checked by:		Date:
Distribution Method	AASHTO Formula		Sealed By:		Date:
Impact Factor	25.2%	(axle loading)	FL P.E. No.:	75976	
FL120 Gov. Span Length	10.8	(feet)	Cert. Auth. No.:	Government Agency	
Recommended Posting	At/Above legal loads. Posting Not Required.		Phone & email:	850-410-5531, CO-LoadRating@dot.state.fl.us	
Recommended SU Posting	99	(tons)	Company:	FDOT	
Recommended C Posting	99	(tons)	Address:	2740 Centerview Dr. #1B, Tallahassee FL 32399	
Recommended ST5 Posting	99	(tons)	*P.E. Seal*		
Floor Beam Present?	No				
Segmental Bridge?	No				
Project No. & Reason	12345-1234	Update			
Plans Status	Built				
Software Name, Version	FDOT Hinged-End Culvert (2016 04-04)				

COMMENTS BY THE ENGINEER

Contents: summary, narrative, plans, calcs, check.

See load rating narrative.

Example. Ficticious Bridge No. and Bridge Name.

This 04-12-2016 table follows the 2016 FDOT Bridge Load Rating Manual, and the BMS Coding Guide. See www.dot.state.fl.us/statemaintenanceoffice/LoadRating.shtm

HL93.INV	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 1.90ft.
	0	25	5.8	8.8	2.366		RF = (20.46 - 4.46) / (1.75* 0.1304*1.252*65.8) = 0.85
	4	25	1.8	4.8	2.366		
HL93.INV	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 2.60ft.
	0	25	5.1	9.0	1.597		RF = (20.46 - 5.57) / (1.75* 0.1141*1.223*64.8) = 0.94
	4	25	1.1	5.0	1.597		
HL93.INV	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 1.90ft.
	0	8	30.6	33.6	0.757		RF = (-20.46 - -5.57) / (1.75* 0.1304*1.252*-47.6) = 1.09
	14	32	16.6	19.6	3.029		
	14	32	2.6	5.6	3.029		
HL93.INV	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 2.60ft.
	0	8	30.2	34.0	0.511		RF = (-20.46 - -6.95) / (1.75* 0.1141*1.223*-47.0) = 1.18
	14	32	16.2	20.0	2.044		
	14	32	2.2	6.0	2.044		
HL93.INV	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 1.90ft.
	0	25	6.6	9.6	2.366		RF = (-12.55 - -2.55) / (1.75* 0.1304*1.252*-32.5) = 1.08
	4	25	2.6	5.6	2.366		
HL93.INV	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 2.60ft.
	0	25	6.0	9.8	1.597		RF = (-13.61 - -3.18) / (1.75* 0.1141*1.223*-30.7) = 1.39
	4	25	2.0	5.8	1.597		
HL93.INV	ft	kip	h.eq(ft)			M.wall	Ext Wall at 0.48, D.fill = 2.60ft.
	0	8	2.6				RF = [1.75/1.75][1.20/1.20][36/36][(12.10 - 7.52) / (3.24)] = 1.41
	14	32					
	14	32					

Detailed Summary (2 of 10)

HL93.OPR	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 1.90ft.
	0	25	5.8	8.8	1.825		RF = (20.46 - 4.46) / (1.35* 0.1304*1.252*65.8) = 1.10
	4	25	1.8	4.8	1.825		
HL93.OPR	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 2.60ft.
	0	25	5.1	9.0	1.232		RF = (20.46 - 5.57) / (1.35* 0.1141*1.223*64.8) = 1.22
	4	25	1.1	5.0	1.232		
HL93.OPR	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 1.90ft.
	0	8	30.6	33.6	0.584		RF = (-20.46 - -5.57) / (1.35* 0.1304*1.252*-47.6) = 1.42
	14	32	16.6	19.6	2.337		
	14	32	2.6	5.6	2.337		
HL93.OPR	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 2.60ft.
	0	8	30.2	34.0	0.394		RF = (-20.46 - -6.95) / (1.35* 0.1141*1.223*-47.0) = 1.53
	14	32	16.2	20.0	1.577		
	14	32	2.2	6.0	1.577		
HL93.OPR	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 1.90ft.
	0	25	6.6	9.6	1.825		RF = (-13.57 - -2.55) / (1.35* 0.1304*1.252*-32.5) = 1.54
	4	25	2.6	5.6	1.825		
HL93.OPR	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 2.60ft.
	0	25	6.0	9.8	1.232		RF = (-13.61 - -3.18) / (1.35* 0.1141*1.223*-30.7) = 1.80
	4	25	2.0	5.8	1.232		
HL93.OPR	ft	kip	h.eq(ft)			M.wall	Ext Wall at 0.48, D.fill = 2.60ft.
	0	8	2.6				RF = [1.75/1.35][1.20/1.20][36/36][(12.10 - 7.52) / (3.24)] = 1.83
	14	32					
	14	32					

FL120	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 1.90ft.
	0	13.334	31.0	34.0	0.811		RF = (20.46 - 4.46) / (1.35* 0.1087*1.252*98.6) = 0.88
	14	53.333	17.0	20.0	3.245		
	14	53.333	3.0	6.0	3.245		
FL120	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 2.60ft.
	0	13.334	30.7	34.5	0.548		RF = (20.46 - 5.57) / (1.35* 0.0951*1.223*93.6) = 1.01
	14	53.333	16.7	20.5	2.190		
	14	53.333	2.7	6.5	2.190		
FL120	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 1.90ft.
	0	13.334	30.6	33.6	0.811		RF = (-20.46 - -5.57) / (1.35* 0.1087*1.252*-79.3) = 1.02
	14	53.333	16.6	19.6	3.245		
	14	53.333	2.6	5.6	3.245		
FL120	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 2.60ft.
	0	13.334	30.2	34.0	0.548		RF = (-20.46 - -6.95) / (1.35* 0.0951*1.223*-78.4) = 1.10
	14	53.333	16.2	20.0	2.190		
	14	53.333	2.2	6.0	2.190		
FL120	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 1.90ft.
	0	13.334	34.5	37.5	0.811		RF = (-13.09 - -2.55) / (1.35* 0.1087*1.252*-44.2) = 1.30
	14	53.333	20.5	23.5	3.245		
	14	53.333	6.5	9.5	3.245		
FL120	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 2.60ft.
	0	53.333	19.9	23.7	2.190		RF = (-13.61 - -3.18) / (1.35* 0.0951*1.223*-43.0) = 1.55
	14	53.333	5.9	9.7	2.190		
	14	13.334	-8.1	-4.3	0.548		
FL120	ft	kip	h.eq(ft)			M.wall	Ext Wall at 0.48, D.fill = 2.60ft.
	0	13.334	2.6				RF = [1.75/1.35][1.20/1.00][36/60][(12.10 - 7.52) / (3.24)] = 1.32
	14	53.333					
	14	53.333					

SU2	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 1.90ft.
	0	12	15.9	18.9	0.730		RF = (20.46 - 4.46) / (1.35* 0.1087*1.252*40.6) = 2.15
	13	22	2.9	5.9	1.339		
SU2	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 2.60ft.
	0	12	15.5	19.4	0.493		RF = (20.46 - 5.57) / (1.35* 0.0951*1.223*38.6) = 2.46
	13	22	2.5	6.4	0.903		
SU2	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 1.90ft.
	0	12	16.8	19.8	0.730		RF = (-20.46 - -5.57) / (1.35* 0.1087*1.252*-29.6) = 2.74
	13	22	3.8	6.8	1.339		
SU2	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 2.60ft.
	0	12	16.1	20.0	0.493		RF = (-20.46 - -6.95) / (1.35* 0.0951*1.223*-29.1) = 2.95
	13	22	3.1	7.0	0.903		
SU2	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 1.90ft.
	0	12	19.7	22.7	0.730		RF = (-15.87 - -2.55) / (1.35* 0.1087*1.252*-18.5) = 3.92
	13	22	6.7	9.7	1.339		
SU2	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 2.60ft.
	0	12	18.8	22.6	0.493		RF = (-13.61 - -3.18) / (1.35* 0.0951*1.223*-17.8) = 3.73
	13	22	5.8	9.6	0.903		
SU2	ft	kip	h.eq(ft)			M.wall	Ext Wall at 0.48, D.fill = 2.60ft.
	0	12	2.6				RF = [1.75/1.35][1.20/1.00][36/17][(12.10 - 7.52) / (3.24)] = 4.66
	13	22					
SU3	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 1.90ft.
	0	22	5.9	9.0	1.339		RF = (20.46 - 4.46) / (1.35* 0.1087*1.252*56.6) = 1.54
	4.17	22	1.8	4.8	1.339		
	11	22	-9.2	-6.2	1.339		

SU3	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 2.60ft.
	0	22	5.3	9.1	0.903		RF = (20.46 - 5.57) / (1.35* 0.0951*1.223*55.7) = 1.70
	4.17	22	1.1	5.0	0.903		
	11	22	-9.9	-6.0	0.903		
SU3	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 1.90ft.
	0	22	16.5	19.6	1.339		RF = (-20.46 - -5.57) / (1.35* 0.1087*1.252*-51.1) = 1.58
	11	22	5.5	8.6	1.339		
	4.17	22	1.4	4.4	1.339		
SU3	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 2.60ft.
	0	22	15.9	19.7	0.903		RF = (-20.46 - -6.95) / (1.35* 0.0951*1.223*-50.4) = 1.71
	11	22	4.9	8.7	0.903		
	4.17	22	0.7	4.5	0.903		
SU3	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 1.90ft.
	0	22	17.8	20.8	1.339		RF = (-14.62 - -2.55) / (1.35* 0.1087*1.252*-28.9) = 2.28
	11	22	6.8	9.8	1.339		
	4.17	22	2.6	5.6	1.339		
SU3	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 2.60ft.
	0	22	16.8	20.6	0.903		RF = (-13.39 - -3.18) / (1.35* 0.0951*1.223*-27.5) = 2.37
	11	22	5.8	9.6	0.903		
	4.17	22	1.6	5.5	0.903		
SU3	ft	kip	h.eq(ft)			M.wall	Ext Wall at 0.48, D.fill = 2.60ft.
	0	22	2.6				RF = [1.75/1.35][1.20/1.00][36/33][(12.10 - 7.52) / (3.24)] = 2.40
	11	22					
	4.17	22					

SU4	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 1.90ft.
	0	18.7	7.2	10.2	1.138		RF = (20.46 - 4.46) / (1.35* 0.1087*1.252*50.0) = 1.74
	4.17	18.7	3.0	6.0	1.138		
	4.17	18.7	-1.2	1.9	1.138		
	9.17	13.9	-10.3	-7.3	0.846		
SU4	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 2.60ft.
	0	18.7	6.9	10.7	0.768		RF = (20.46 - 5.57) / (1.35* 0.0951*1.223*49.4) = 1.92
	4.17	18.7	2.7	6.5	0.768		
	4.17	18.7	-1.5	2.4	0.768		
	9.17	13.9	-10.6	-6.8	0.571		
SU4	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 1.90ft.
	0	13.9	20.6	23.6	0.846		RF = (-20.46 - -5.57) / (1.35* 0.1087*1.252*-44.9) = 1.81
	9.17	18.7	11.4	14.4	1.138		
	4.17	18.7	7.3	10.3	1.138		
	4.17	18.7	3.1	6.1	1.138		
SU4	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 2.60ft.
	0	13.9	15.1	18.9	0.571		RF = (-20.46 - -6.95) / (1.35* 0.0951*1.223*-44.2) = 1.95
	9.17	18.7	6.0	9.8	0.768		
	4.17	18.7	1.8	5.6	0.768		
	4.17	18.7	-2.4	1.4	0.768		
SU4	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 1.90ft.
	0	13.9	15.9	18.9	0.846		RF = (-14.86 - -2.55) / (1.35* 0.1087*1.252*-25.6) = 2.62
	9.17	18.7	6.7	9.7	1.138		
	4.17	18.7	2.6	5.6	1.138		
	4.17	18.7	-1.6	1.4	1.138		
SU4	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 2.60ft.
	0	13.9	15.1	18.9	0.571		RF = (-13.29 - -3.18) / (1.35* 0.0951*1.223*-24.1) = 2.67
	9.17	18.7	6.0	9.8	0.768		
	4.17	18.7	1.8	5.6	0.768		
	4.17	18.7	-2.4	1.4	0.768		
SU4	ft	kip	h.eq(ft)			M.wall	Ext Wall at 0.48, D.fill = 2.60ft.
	0	13.9	2.6				RF = [1.75/1.35][1.20/1.00][36/35][(12.10 - 7.52) / (3.24)] = 2.26
	9.17	18.7					
	4.17	18.7					
	4.17	18.7					

C3	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 1.90ft.
	0	22	23.1	26.1	1.339		RF = (20.46 - 4.46) / (1.35* 0.1087*1.252*42.7) = 2.04
	20	22	3.1	6.1	1.339		
	10	12	-6.9	-3.9	0.730		
C3	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 2.60ft.
	0	22	22.6	26.4	0.903		RF = (20.46 - 5.57) / (1.35* 0.0951*1.223*40.5) = 2.34
	20	22	2.6	6.4	0.903		
	10	12	-7.4	-3.6	0.493		
C3	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 1.90ft.
	0	12	14.3	17.3	0.730		RF = (-20.46 - -5.57) / (1.35* 0.1087*1.252*-33.4) = 2.42
	10	22	4.3	7.3	1.339		
	20	22	-15.7	-12.7	1.339		
C3	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 2.60ft.
	0	12	14.1	18.0	0.493		RF = (-20.46 - -6.95) / (1.35* 0.0951*1.223*-32.8) = 2.62
	10	22	4.1	8.0	0.903		
	20	22	-15.9	-12.0	0.903		
C3	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 1.90ft.
	0	12	16.6	19.6	0.730		RF = (-15.81 - -2.55) / (1.35* 0.1087*1.252*-19.0) = 3.80
	10	22	6.6	9.6	1.339		
	20	22	-13.4	-10.4	1.339		
C3	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 2.60ft.
	0	12	15.5	19.4	0.493		RF = (-13.52 - -3.18) / (1.35* 0.0951*1.223*-17.8) = 3.69
	10	22	5.5	9.4	0.903		
	20	22	-14.5	-10.6	0.903		
C3	ft	kip	h.eq(ft)			M.wall	Ext Wall at 0.48, D.fill = 2.60ft.
	0	12	2.6				RF = [1.75/1.35][1.20/1.00][36/28][(12.10 - 7.52) / (3.24)] = 2.83
	10	22					
	20	22					

C4	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 1.90ft.
	0	7.3	37.7	40.7	0.444		RF = (20.46 - 4.46) / (1.35* 0.1087*1.252*58.3) = 1.50
	10	22	27.7	30.7	1.339		
	21.83	22	5.8	8.9	1.339		
	4.17	22	1.7	4.7	1.339		
C4	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 2.60ft.
	0	7.3	37.3	41.1	0.300		RF = (20.46 - 5.57) / (1.35* 0.0951*1.223*57.3) = 1.66
	10	22	27.3	31.1	0.903		
	21.83	22	5.5	9.3	0.903		
	4.17	22	1.3	5.1	0.903		
C4	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 1.90ft.
	0	7.3	38.2	41.2	0.444		RF = (-20.46 - -5.57) / (1.35* 0.1087*1.252*-39.6) = 2.05
	10	22	28.2	31.2	1.339		
	21.83	22	6.4	9.4	1.339		
	4.17	22	2.2	5.2	1.339		
C4	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 2.60ft.
	0	7.3	37.8	41.6	0.300		RF = (-20.46 - -6.95) / (1.35* 0.0951*1.223*-38.8) = 2.21
	10	22	27.8	31.6	0.903		
	21.83	22	6.0	9.8	0.903		
	4.17	22	1.8	5.6	0.903		
C4	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 1.90ft.
	0	7.3	38.7	41.7	0.444		RF = (-14.74 - -2.55) / (1.35* 0.1087*1.252*-27.8) = 2.39
	10	22	28.7	31.7	1.339		
	21.83	22	6.9	9.9	1.339		
	4.17	22	2.7	5.7	1.339		
C4	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 2.60ft.
	0	7.3	37.8	41.6	0.300		RF = (-13.61 - -3.18) / (1.35* 0.0951*1.223*-26.6) = 2.50
	10	22	27.8	31.6	0.903		
	21.83	22	6.0	9.8	0.903		
	4.17	22	1.8	5.6	0.903		
C4	ft	kip	h.eq(ft)			M.wall	Ext Wall at 0.48, D.fill = 2.60ft.
	0	7.3	2.6				RF = [1.75/1.35][1.20/1.00][36/36.65][(12.10 - 7.52) / (3.24)] = 2.16
	10	22					
	21.83	22					
	4.17	22					

C5	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 1.90ft.
	0	15	27.8	30.8	0.913		RF = (20.46 - 4.46) / (1.35* 0.1087*1.252*54.1) = 1.61
	4.17	15	23.6	26.6	0.913		
	17.67	20	6.0	9.0	1.217		
	4.17	20	1.8	4.8	1.217		
	10	10	-8.2	-5.2	0.608		
C5	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 2.60ft.
	0	15	27.3	31.1	0.616		RF = (20.46 - 5.57) / (1.35* 0.0951*1.223*53.2) = 1.78
	4.17	15	23.1	26.9	0.616		
	17.67	20	5.4	9.2	0.821		
	4.17	20	1.2	5.1	0.821		
	10	10	-8.8	-4.9	0.411		
C5	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 1.90ft.
	0	10	15.8	18.8	0.608		RF = (-20.46 - -5.57) / (1.35* 0.1087*1.252*-42.3) = 1.92
	10	20	5.8	8.8	1.217		
	4.17	20	1.7	4.7	1.217		
	17.67	15	-16.0	-13.0	0.913		
	4.17	15	-20.2	-17.2	0.913		
C5	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 2.60ft.
	0	10	15.6	19.5	0.411		RF = (-20.46 - -6.95) / (1.35* 0.0951*1.223*-41.6) = 2.07
	10	20	5.6	9.5	0.821		
	4.17	20	1.5	5.3	0.821		
	17.67	15	-16.2	-12.4	0.616		
	4.17	15	-20.4	-16.6	0.616		
C5	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 1.90ft.
	0	10	16.9	19.9	0.608		RF = (-14.97 - -2.55) / (1.35* 0.1087*1.252*-25.8) = 2.62
	10	20	6.9	9.9	1.217		
	4.17	20	2.7	5.7	1.217		
	17.67	15	-15.0	-11.9	0.913		
	4.17	15	-19.1	-16.1	0.913		
C5	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 2.60ft.
	0	10	16.2	20.0	0.411		RF = (-13.61 - -3.18) / (1.35* 0.0951*1.223*-24.5) = 2.72
	10	20	6.2	10.0	0.821		
	4.17	20	2.0	5.8	0.821		
	17.67	15	-15.7	-11.9	0.616		
	4.17	15	-19.9	-16.0	0.616		
C5	ft	kip	h.eq(ft)			M.wall	Ext Wall at 0.48, D.fill = 2.60ft.
	0	10	2.6				RF = [1.75/1.35][1.20/1.00][36/40][(12.10 - 7.52) / (3.24)] = 1.98
	10	20					
	4.17	20					
	17.67	15					
	4.17	15					

ST5	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 1.90ft.
	0	18	41.8	44.9	1.095		RF = (20.46 - 4.46) / (1.35* 0.1087*1.252*47.4) = 1.84
	24	18	17.8	20.9	1.095		
	12	18	5.8	8.9	1.095		
	4	18	1.8	4.9	1.095		
	27	8	-25.2	-22.1	0.487		
ST5	ft	kip	start(ft)	end(ft)	klf	M.pos	Top Slab at 1.40, D.fill = 2.60ft.
	0	18	41.0	44.8	0.739		RF = (20.46 - 5.57) / (1.35* 0.0951*1.223*46.6) = 2.03
	24	18	17.0	20.8	0.739		
	12	18	5.0	8.8	0.739		
	4	18	1.0	4.8	0.739		
	27	8	-26.0	-22.2	0.329		
ST5	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 1.90ft.
	0	18	41.0	44.0	1.095		RF = (-20.46 - -5.57) / (1.35* 0.1087*1.252*-39.7) = 2.04
	24	18	17.0	20.0	1.095		
	12	18	5.0	8.0	1.095		
	4	18	1.0	4.0	1.095		
	27	8	-26.0	-23.0	0.487		
ST5	ft	kip	start(ft)	end(ft)	klf	M.neg	Top Slab at 2.00, D.fill = 2.60ft.
	0	18	41.0	44.8	0.739		RF = (-20.46 - -6.95) / (1.35* 0.0951*1.223*-39.1) = 2.20
	24	18	17.0	20.8	0.739		
	12	18	5.0	8.8	0.739		
	4	18	1.0	4.8	0.739		
	27	8	-26.0	-22.2	0.329		
ST5	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 1.90ft.
	0	18	42.7	45.7	1.095		RF = (-15.19 - -2.55) / (1.35* 0.1087*1.252*-24.0) = 2.87
	24	18	18.7	21.7	1.095		
	12	18	6.7	9.7	1.095		
	4	18	2.7	5.7	1.095		
	27	8	-24.3	-21.3	0.487		
ST5	ft	kip	start(ft)	end(ft)	klf	V.neg	Top Slab at 1.90, D.fill = 2.60ft.
	0	18	41.8	45.6	0.739		RF = (-13.58 - -3.18) / (1.35* 0.0951*1.223*-22.5) = 2.94
	24	18	17.8	21.6	0.739		
	12	18	5.8	9.6	0.739		
	4	18	1.8	5.6	0.739		
	27	8	-25.2	-21.4	0.329		
ST5	ft	kip	h.eq(ft)			M.wall	Ext Wall at 0.48, D.fill = 2.60ft.
	0	8	2.6				RF = [1.75/1.35][1.20/1.00][36/40][(12.10 - 7.52) / (3.24)] = 1.98
	27	18					
	4	18					
	12	18					
	24	18					

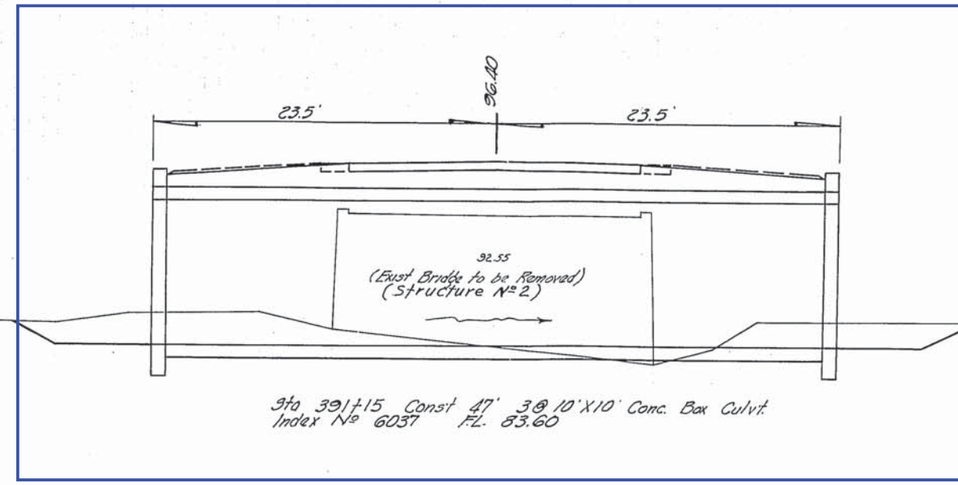
Narrative

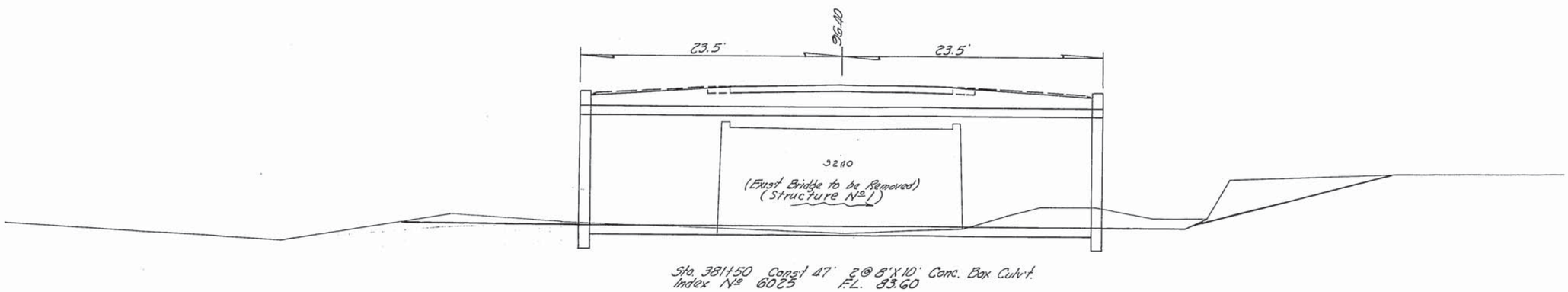
NOTE: This is an example. Names and identifying numbers are fictitious.

HISTORY. In 1958, Proj. 12345-1234 constructed Culvert No. 999999, CR123 over Culvert Creek, 7.2 miles North of SR40. This bridge load rating is an update.

CONDITION. On 04-01-2016, Mario Bauza performed an interim inspection, finding satisfactory culvert condition (NBI Item No. 62 = 6), and poor channel condition (NBI Item No. 61 = 4). The channel bends 90 degrees on both sides of this unskewed culvert, two wingwalls are undermined, and the recommended scour countermeasures have not been implemented. Additional undermining will compromise the wingwalls, the slopes, and the structural integrity of the culvert. Repairs have been recommended. However the scouring defects do not affect the load carrying capacity at this time, spalling and deterioration is incidental, and full sections still apply.

[redacted]



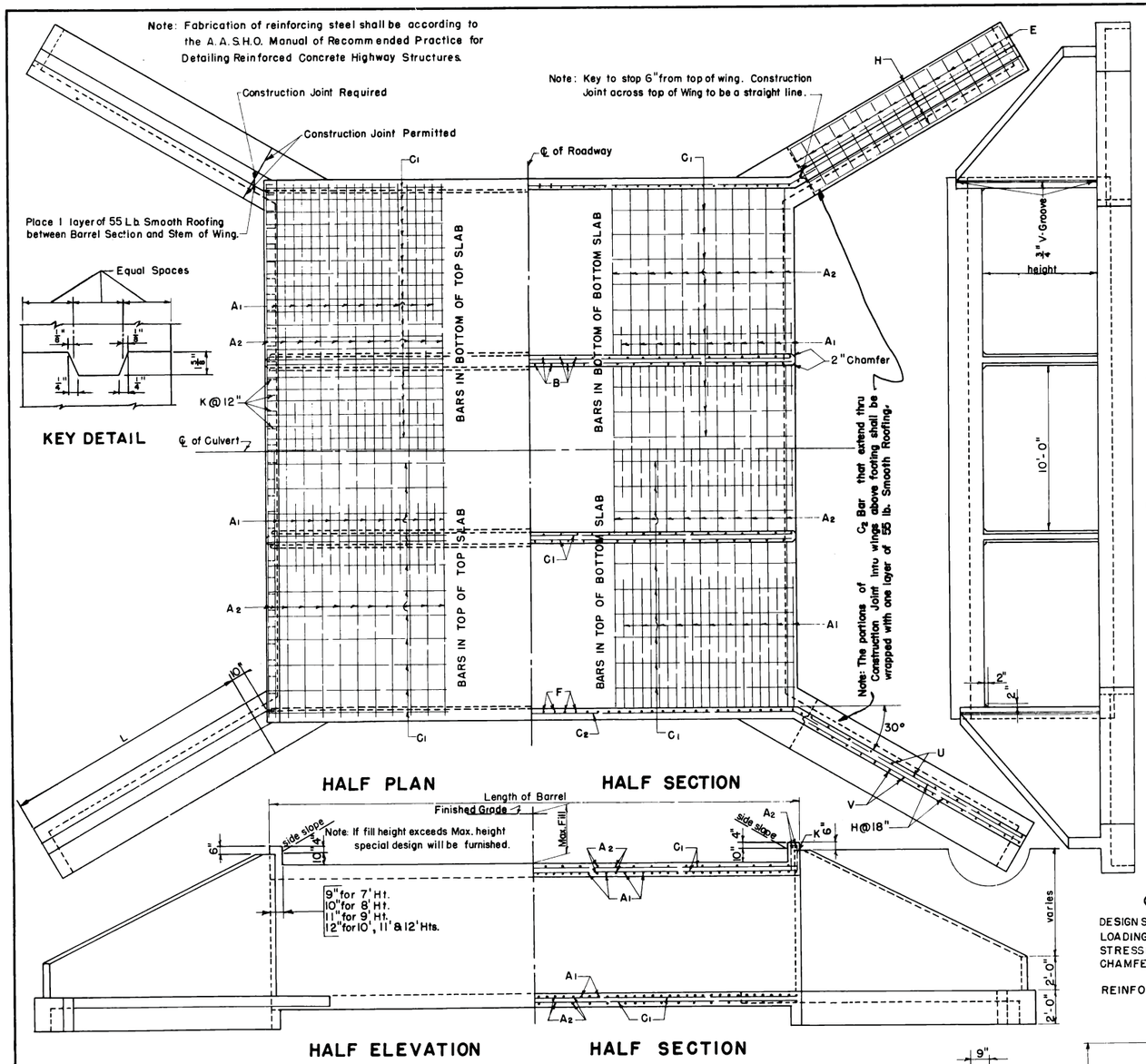


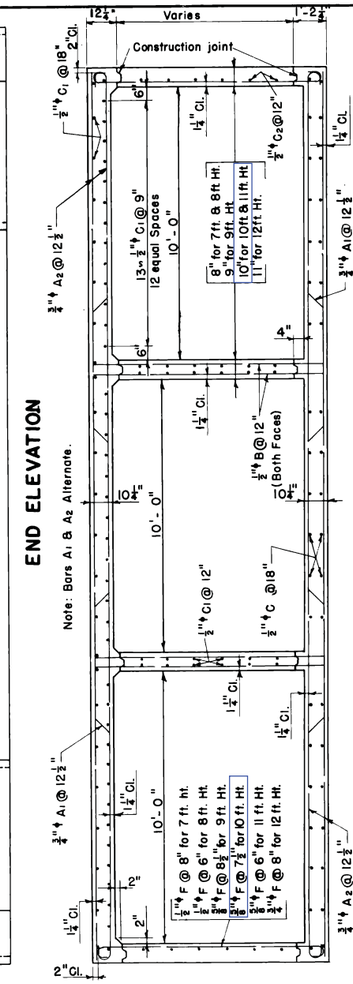
30 20 10 ℄ 10 20 30

PROPOSED DRAINAGE STRUCTURES

FED. ROAD DIV. No	STATE	SECTION	JOB No.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
3	FLA.					

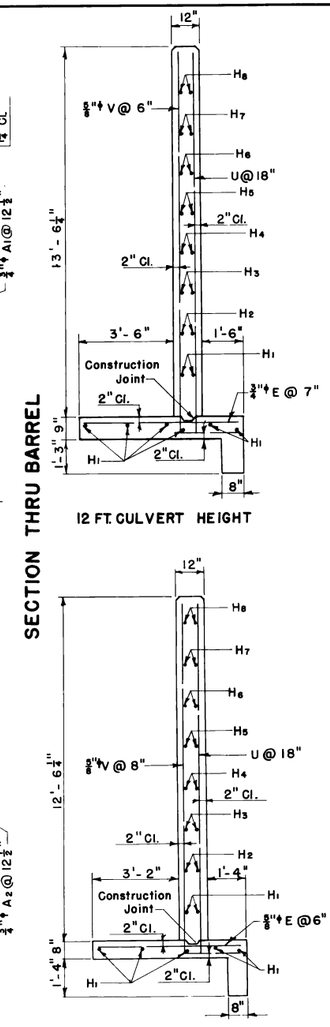
Note: Fabrication of reinforcing steel shall be according to the A.A.S.H.O. Manual of Recommended Practice for Detailing Reinforced Concrete Highway Structures.





GENERAL NOTES

DESIGN SPECIFICATIONS: A.A.S.H.O. 1949.
LOADING: H-15-44.
STRESSES: fs = 20,000 fc = 1,000.
CHAMFER: All edges and corners to be chamfered 3/4" unless otherwise noted.
REINFORCING STEEL SPECIFICATIONS: A.A.S.H.O. M-137.



REINFORCING STEEL

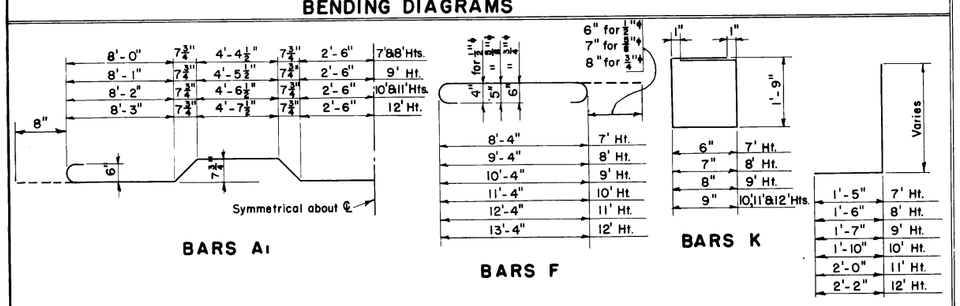
CULVERT HEIGHT		7'-0"		8'-0"		9'-0"		10'-0"		11'-0"		12'-0"	
MARK	SIZE	NO.	LENGTH	NO.	LENGTH	NO.	LENGTH	NO.	LENGTH	NO.	LENGTH	NO.	LENGTH
A1	3/4"ϕ	*	34'-7"	*	34'-7"	*	34'-11"	*	35'-3"	*	35'-3"	*	35'-7"
A2	3/4"ϕ	*	32'-4"	*	32'-4"	*	32'-8"	*	33'-0"	*	33'-0"	*	33'-4"
B	1/2"ϕ	*	8'-4"	*	9'-4"	*	10'-4"	*	11'-4"	*	12'-4"	*	13'-4"
C1	1/2"ϕ	133	**	137	**	141	**	145	**	149	**	153	**
C2	1/2"ϕ	12	***	14	***	16	***	18	***	20	***	22	***
E	See Section	64	3'-1"	72	3'-8"	136	4'-2"	132	4'-8"	196	5'-2"	184	5'-8"
F	" "	*	9'-4"	*	10'-4"	*	11'-6"	*	12'-6"	*	13'-6"	*	14'-8"
H1	1/2"ϕ	28	14'-11"	28	17'-2"	28	19'-5"	28	21'-8"	28	24'-2"	32	26'-5"
H2	1/2"ϕ	8	12'-4"	8	15'-10"	8	16'-11"	8	19'-2"	8	22'-10"	8	23'-11"
H3	1/2"ϕ	8	8'-10"	8	12'-4"	8	13'-5"	8	15'-9"	8	19'-4"	8	20'-5"
H4	1/2"ϕ	8	5'-4"	8	8'-10"	8	10'-0"	8	12'-3"	8	15'-10"	8	17'-0"
H5	1/2"ϕ	8	1'-10"	8	5'-5"	8	6'-6"	8	8'-10"	8	12'-4"	8	13'-6"
H6	1/2"ϕ			8	1'-11"	8	3'-1"	8	5'-4"	8	8'-11"	8	10'-0"
H7	1/2"ϕ							8	1'-11"	8	5'-5"	8	6'-6"
H8	1/2"ϕ									8	1'-11"	8	3'-1"
K	1/2"ϕ	66	4'-6"	66	4'-9"	66	5'-0"	68	5'-3"	68	5'-3"	68	5'-3"
U1	1/2"ϕ	8	2'-8"	8	2'-6"	8	2'-8"	8	2'-7"	8	2'-5"	8	2'-8"
U2	1/2"ϕ	8	4'-0"	8	3'-10"	8	4'-0"	8	3'-10"	8	3'-9"	8	4'-0"
U3	1/2"ϕ	8	5'-3"	8	5'-2"	8	5'-4"	8	5'-2"	8	5'-0"	8	5'-3"
U4	1/2"ϕ	8	6'-7"	8	6'-5"	8	6'-7"	8	6'-5"	8	6'-4"	8	6'-7"
U5	1/2"ϕ	8	7'-10"	8	7'-9"	8	7'-11"	8	7'-9"	8	7'-7"	8	7'-10"
U6	1/2"ϕ			8	9'-0"	8	9'-2"	8	9'-0"	8	8'-11"	8	9'-1"
U7	1/2"ϕ					4	10'-6"	8	10'-4"	8	10'-2"	8	10'-5"
U8	1/2"ϕ							4	11'-7"	8	11'-6"	8	11'-8"
U9	1/2"ϕ									4	12'-9"	8	13'-0"
V1	See Section	8	3'-8"	8	3'-10"	8	3'-10"	8	4'-2"	8	4'-4"	8	4'-8"
V2	" "	8	4'-5"	8	4'-9"	8	4'-6"	8	4'-8"	8	4'-11"	8	5'-1"
V3	" "	8	5'-3"	8	5'-7"	8	5'-2"	8	5'-2"	8	5'-6"	8	5'-6"
V4	" "	8	6'-1"	8	6'-5"	8	5'-10"	8	5'-8"	8	6'-1"	8	5'-11"
V5	" "	8	7'-0"	8	7'-4"	8	6'-6"	8	6'-2"	8	6'-8"	8	6'-4"
V6	" "	8	7'-10"	8	8'-2"	8	7'-2"	8	6'-8"	8	7'-3"	8	6'-10"
V7	" "	8	8'-8"	8	9'-0"	8	7'-9"	8	7'-2"	8	7'-9"	8	7'-3"
V8	" "	8	9'-5"	8	9'-11"	8	8'-5"	8	7'-8"	8	8'-4"	8	7'-8"
V9	" "			8	10'-9"	8	9'-1"	8	8'-2"	8	8'-11"	8	8'-1"
V10	" "					8	9'-9"	8	8'-8"	8	9'-6"	8	8'-6"
V11	" "					8	10'-4"	8	9'-2"	8	10'-1"	8	9'-0"
V12	" "					8	11'-0"	8	9'-8"	8	10'-8"	8	9'-5"
V13	" "					8	11'-8"	8	10'-3"	8	11'-3"	8	9'-10"
V14	" "					4	12'-4"	8	10'-9"	8	11'-10"	8	10'-3"
V15	" "							8	11'-3"	8	12'-5"	8	10'-8"
V16	" "							8	11'-9"	8	12'-11"	8	11'-2"
V17	" "							8	12'-3"	8	13'-6"	8	11'-7"
V18	" "							8	12'-9"	8	14'-1"	8	12'-0"
V19	" "							8	13'-3"	4	14'-8"	8	12'-5"
V20	" "											8	12'-10"
V21	" "											8	13'-4"
V22	" "											8	13'-9"
V23	" "											8	14'-2"
V24	" "											8	14'-7"
V25	" "											8	15'-0"
V26	" "											12	15'-5"

DIMENSIONS / QUANTITIES

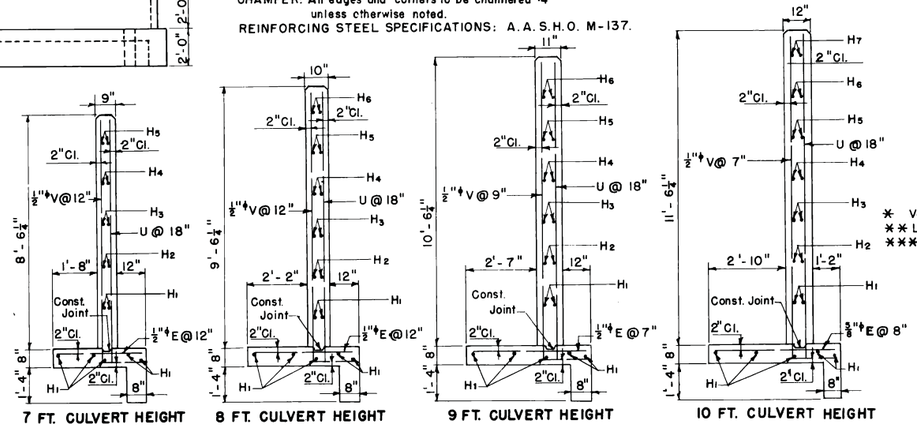
CULVERT HEIGHT	AREA OF OPENING	MAXIMUM FILL HEIGHT	L	32' BARREL LENGTH: CONCRETE CU. YD.	32' BARREL LENGTH: REINF. STEEL LBS.	ADDITIONAL LENGTH: CONC. CU. YD. PER LIN. FT.	ADDITIONAL LENGTH: REINF. STEEL LBS. PER LIN. FT.
7'-0"	209.92	5'-0"	15'-3"	110.06	14,837.	2.761	424.05
8'-0"	239.92	5'-0"	17'-6"	119.62	15,641.	2.860	439.64
9'-0"	269.92	5'-0"	19'-9"	134.25	16,699.	3.091	455.46
10'-0"	299.92	5'-0"	22'-0"	150.73	18,022.	3.347	472.88
11'-0"	329.92	5'-0"	24'-6"	162.22	19,923.	3.470	494.16
12'-0"	359.92	5'-0"	26'-9"	180.89	22,070.	3.763	513.49

* Varies with length of Barrel.
** Length of Barrel minus 4".
*** Length of Barrel plus 4'-2".

BENDING DIAGRAMS



Note: All bar dimensions are given out to out.



STATE OF FLORIDA
STATE ROAD DEPARTMENT

TRIPLE 10FT. SPAN CULVERT
7·8·9·10·11·12 FT. HEIGHTS

ROAD NO.	COUNTY	SECTION	JOB NO.

REVISIONS		
Names	Dates	Descriptions

	Names	Dates
Designed by	W. H. M.	4 - 51
Checked by	R. M. M.	4 - 51
Drawn by	W. H. W.	6 - 51
Checked by	M. E. F.	6 - 51
Quantities by	P. H. S.	6 - 51
Checked by	M. E. F.	6 - 51
Traced by	W. H. W.	6 - 51

T. W. Jennings

Drawing No. 1 of 1

Index No. 6037

Depth of Fill

$$LOC := \begin{pmatrix} \text{"SB Top of Headwall"} \\ \text{"SB Outside Shoulder Stripe"} \\ \text{"CL Divisor Stripe"} \\ \text{"NB Outside Shoulder Stripe"} \\ \text{"NB Top of Headwall"} \end{pmatrix} \quad Dist := \begin{pmatrix} -5 \\ 5 \\ 17 \\ 29 \\ 39 \end{pmatrix} ft \quad FS := \begin{pmatrix} 5.9 \\ 5.0 \\ 4.5 \\ 5.1 \\ 6.1 \end{pmatrix} ft$$

Dist - horizontal distance from beginning to culvert to rod
FS - foresights, vertical rod readings
HI = 0 - say height of instrument elevation is 0 feet

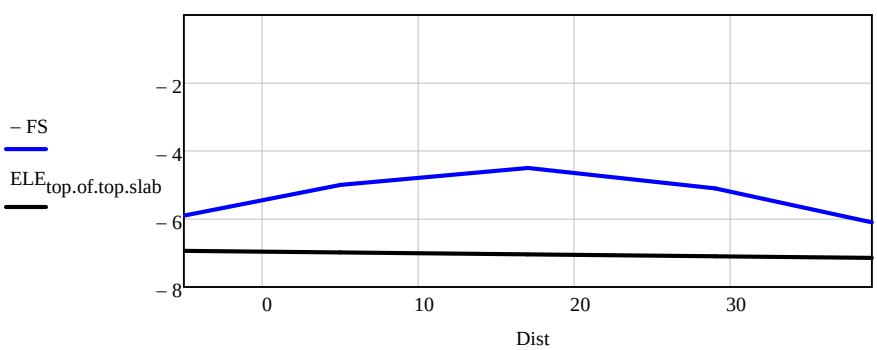
$$ELE_{top.of.top.slab_start} := -FS_1 - 23in + 10.25in = -6.96\,ft$$

$$ELE_{top.of.top.slab_end} := -FS_{rows(FS)} - 23in + 10.25in = -7.16\,ft$$

$$ELE_{top.of.top.slab} := ELE_{top.of.top.slab_start} + \frac{ELE_{top.of.top.slab_end} - ELE_{top.of.top.slab_start}}{Dist_{rows(Dist)} - Dist_1} \cdot Dist$$

$$FillHeights := -\left(FS + ELE_{top.of.top.slab}\right)$$

$FillHeights^T = (1.04 \quad 1.99 \quad 2.54 \quad 1.99 \quad 1.04)\,ft$. Traffic-carrying fill depths range from 2.0 to 2.5 feet. *Say 1.9 ft. < D.fill < 2.6 ft.*



Inputs

BridgeNo := "999999"

BridgeName := "CR123 over Culvert Ck"

BridgeDescription := "Index 6037 Triple 10x10, 1958"

VehSet :=

HL93+FL120+7LGL	LRFR-LRFD
HL93+FL120	LRFR-LRFD
HS20+7LGL	LOAD FACTOR
HS20	LOAD FACTOR

$\psi_c := 1.00$ — ψ_c - condition factor

$D_{fills} := \begin{pmatrix} 1.9ft \\ 2.6ft \end{pmatrix}$ — D_{fills} - covering fill depths, roadway surface to top of top slab

cells := 3 — cells - number of barrels

$W_c := 10ft$ — W_c - barrel width, length of clear span

$t_{slab} := 10.25in$ $t_{ExtWall} := 10in$ $t_{IntWall} := 10in$ — t_{slab} $t_{ExtWall}$ $t_{IntWall}$ - thicknesses: top slab, exterior wall, interior wall

$A_s := 0.44in^2 \cdot \frac{12in}{0.5 \cdot 12.5in} = 0.845 \cdot in^2$ — A_s - area of tension reinforcement per strip foot, top slab

$d := t_{slab} - \left(1.25in + \frac{1}{2} \cdot \frac{6}{8} in\right) = 8.62 \cdot in$ — d - distance from compression face to centroid of tension steel, top slab

$A_{s.wall} := 0.31in^2 \cdot \frac{12in}{7.5in} = 0.50 \cdot in^2$ — $A_{s.wall}$ - area of positive moment reinforcement per strip foot, exterior wall

$d_{wall} := t_{ExtWall} - \left(1.25in + \frac{1}{2} \cdot \frac{5}{8} in\right) = 8.44 \cdot in$ — d_{wall} - distance from compression face to centroid of tension steel, exterior wall

$f_y := 40ksi$ $f_c := 3.0ksi$ — f_y - steel yield and f_c - concrete strength (BLRM Tables 6A.5.2.1-1 and 6A.5.2.2-1)

$h_{clear} := 10ft$ — h_{clear} - clear height of box opening

$h_{haunch.top} := 2in$ $h_{haunch.bot} := 4in$ — $h_{haunch.top}$ & $h_{haunch.bot}$ - haunch heights, top and bottom

$L_{wall} := h_{clear} - \left(h_{haunch.top} + h_{haunch.bot}\right) = 9.50 ft$ — L_{wall} - effective length of the exterior wall, pin-to-pin

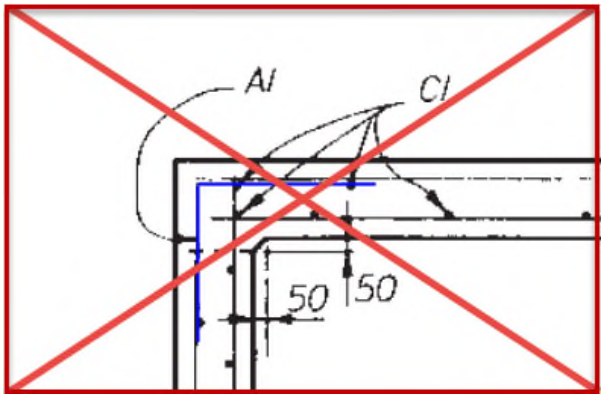
Instructions

(1) INPUT. Adjust inputs on the 1st page. All primary inputs are confined to this one page.
(2) FOOTER. Adjust bottom left footer (View -> Header and Footer -> Footer).
(3) CALCULATE. Scroll to the bottom of the worksheet, or use CTRL+F9 (Tools -> Calculate -> Calculate Worksheet).
This worksheet automatically exports results to "FDOT HINGED-END CULVERT (YEAR MO-DD).xlsm," sheet DATA.
(4) PRINT this MathCAD worksheet (after expanding the collapsed area "Expand this area to print").
(5) PRINT Excel file "FDOT HINGED-END CULVERT (YEAR MO-DD).xlsm" as follows:
Open sheet "SUMMARY." Review, adjust as necessary, and print.
Open sheet "SUMMARY_DETAILED," select print area, adjust page breaks, and print details.

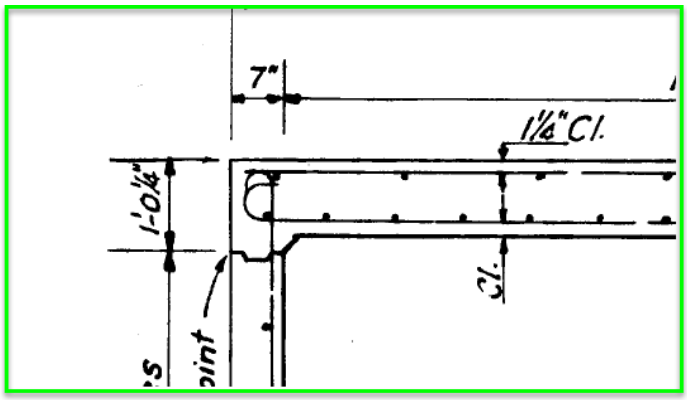
Applicability

This worksheet provides actionable guidance for load rating old-style hinged-end cast-in-place box culverts built to Florida Standard Indices drawn prior to 1970, where:
(1) Outside corners are unreinforced.
(2) Top and bottom slabs are identically reinforced in the primary direction, and uniformly thick.
(3) "Crank bars" provide identical positive and negative moment reinforcement in the slabs.
(4) Barrel widths are less than 15 feet.
(5) The shoulder is adequate; the distance from any lane centerline to its nearest culvert end is greater than one half of the lateral distribution strip width.
As with any software, engineers are responsible for verifying applicability, code compliance, and accuracy. Send questions and suggestions to CO-LoadRating@dot.state.fl.us.

Inapplicable. Frame corners are reinforced.



Applicable. Outside corners are unreinforced; ends are hinged.



Disclaimer

No warranty, expressed or implied, is made by the Florida Department of Transportation (FDOT) as to the accuracy and functioning of this program or the results it produces, nor shall the fact of distribution constitute any such warranty, and no responsibility is assumed by the Florida Department of Transportation in any connection therewith

EXPAND THIS AREA TO PRINT

Outline

(1) INPUTS. Primary inputs are highlighted in green, and confined to a single page.
(2) DISCUSSION. Instructions, applicability, outline, references, calculations discussion, and revisions log.
(3) CALCS. Includes discussion, static inputs tuned for Florida, and calculations.
(4) RESULTS. All results are exported to "FDOT HINGED-END CULVERT (YEAR MO-DD).xlsm;" see sheet "DATA."
(5) QUICK CHECK. Reproduce the rating factors for the selected test vehicle.

References

ACI 318, Current. Building Code Requirements for Structural Concrete (ACI)
FDOT Bridge Management System Coding Guide, 2015 (FDOT BMS Coding)
FDOT Bridge Load Rating Manual, 2016 (BLRM)
FDOT Structures Design Guidelines Volume 1, 2016 (SDG)
AASHTO LRFD Bridge Design Specifications, 7th Ed. 2014 with 2015 & 2016 Interims (LRFD)
AASHTO Manual for Bridge Evaluation, 2nd Ed. 2010 with 2011, 2013, 2014, 2015, & 2016 Interims (MBE)
AASHTO Standard Specifications for Highway Bridges, 17th Ed. 2002 with 2005 Interims (Std.Spec.)

Discussion

APPLICABILITY. This program applies to typical old-style hinged-end cast-in-place box culverts in Florida built to Standard Indices prior to 1970, where (1) the outside corners omit reinforcement, (2) the top and bottom slabs are identically reinforced and uniformly thick, (3) positive moment reinforcement in the slabs is the same as negative moment reinforcement, thanks to "crank bars," (4) span lengths are less than 15 feet, and (5) the shoulder is adequate; the distance from any lane centerline to its nearest culvert end is greater than one half of the lateral distribution strip width.

ASSUMPTIONS, TOP SLAB. (1) Neglect the bottom slab. The bottom slab experiences less live load than the top slab, because the live load is distributed laterally through the walls before reaching the bottom slab. (2) Neglect top-slab-to-exterior-wall continuity. The outside face of the exterior wall omits reinforcement, which renders the connection pinned. Also neglect top-slab-to-interior-wall continuity. Minimal reinforcement, typically #4 at 12 in. OC, is insufficient to fix the connection. (3) Neglect axial action onto the top slab, from horizontal earth pressures, as mildly beneficial. (4) Approximate the governing location for positive moment as 40% span length for multi-span culverts, and 50% span length for single-span culverts. (5) For all top slab distribution calculations, take the effective span length as the clear span. Meanwhile for load calculations, take the effective span lengths as the distances between wall centerlines. (6) Use singly-reinforced flexural capacity, which is trivially less than doubly-reinforced capacity among typical 1.25in. clear covers.

ASSUMPTIONS, EXTERIOR WALL. (1) Include axial loading, verify that ε.steel > ε.yield, and apply concepts from MBE Appendix G6A. (2) Reduce the effective span length to construction-joint-to-construction-joint. (3) Adapt the HL93 Inventory Rating to all vehicles. Where γ = live load factor, GVW = gross vehicle weight, and GVW.HL93 is assumed to be 36 tons:
RF.Exterior.Wall.Vehicle = (RF.Exterior.Wall.HL93.Inventory)(γ.HL93.Inventory/γ.Vehicle)(GVW.HL93/GVW.Vehicle).

DISTRIBUTION. For LFR and LRFR lateral distribution through earth fill, consider one wheel-line and two wheel-lines (one truck). For LFR distribution through earth fill, additionally consider two adjacent trucks, and two trucks fully overlapped (two trucks), wherein adjacent truck spacing is 4 feet. For both LFR and LRFR, take the best of (slab distribution, earth distribution). For LFR tire distribution, use point loading (conservative); for LRFR, use tire patch loading (code). Apply longitudinal distribution, regardless of fill depth. For LFR, this controverts a narrow reading of Std.Spec 6.4.2, which specifies point loading for culverts under less than 2 feet of fill. However, Std. Spec. provides for alternate rational analyses at 1.1.1, and LRFD 5th Ed. at C4.6.2.10.2 provides that alternative when it explains why longitudinal distribution is reasonable and warranted, even for shallower fills.

LIVE LOAD. LFR appraisals use all axle effects, whereas LRFR ratings use extreme axle effects (LRFD C.3.6.1.3.1). LFR impact is interpolated to a linear, rather than step-wise, factor. LRFR lane loading does not apply to barrel widths less than 15 feet in length (LRFD 3.6.1.3.3), and lane loading has been removed from this worksheet.

SHEAR. Shear is taken at a distance "d" away from the face of the support. Reinforcement is assumed to be fully developed (the development length for typical No. 6 40ksi straight bars is 12.7in., per LRFD 5.11.2.1, which is typically less than the beginning of the bar to d away from face). For structures with sensible bearing lengths and reinforcement details, further investigation is not necessary. However, consider LRFD 5.11.2.1 and 5.11.2.4 for shear in atypical slabs (shear capacity φV requires minimum reinforcement, and this program assumes that the reinforcement is developed at the critical location).

METHODOLOGY. All loading is interpolated to an influence matrix, whose precision is guided by "ips" (increments per span). A one foot equivalent strip is analyzed throughout. Consider minimum and maximum load factors to achieve the worst-case loading, however apply only one load factor per load case type at a time. For example, do not vary EV across different span lengths.

Revision Notes

CHANGE NOTES, JULY 2013
(1) speeded up LL routine - dismissed needless increments
(2) added true coincidency shear capacity (previously vectorization conservatively took max moment for Vn equation)
(3) removed point load simulation; substituted area influence
(3) added check plots for select vehicle
(4) added explicit RF output for all vehicles
(6) LRFD 12.5.5.1 shear strength reduction factor to 0.85
(7) updated to 2013 LRFD Interim (adjust tire width to 20in. + 0.06*L)

CHANGE NOTES FEBRUARY 2015
(1) the program last verified 09-09-13; see #750083 review in EDMS, which compares independent calcs.
(2) excluded the Std.Spec. 24kip Military Tandem, as LFR evaluation omits this truck from HS20 evaluation (FDOT clarification for 2015)
(3) clarified that ϕV = 0.85 for all shear, even for LRFD slab-type fills less than 2feet.
(4) changed shear capacity note to cite simplified shear (LRFD - 5.8.3.4.3, which is by inference the $0.06\cdot\sqrt{fc\cdot ksi} = 1.9\cdot\sqrt{fc\cdot psi}$ terms in Vci Vcw)
(5) changed note for mpf = "...1.00 for FL120 routine permit (MBE 6A.4.5.4.2a-1, footnote a)," removing reference to 2011 FDOT Load Rating Manual.

CHANGE NOTES JULY - NOVEMBER 2015
(1) greatly simplify the governing output, only keeping what is needed to inform the Excel summary
(2) develop exterior wall assessment
(3) discard exact uniform load engine; use point approximations instead
(4) offer truly coincident loading with the possibility of varying load factors - min & max among same element.
(5) use one location per test, i.e. 1.40 for positive moment multi-cell or 1.50 for positive moment single-cell.
(6) reduce discussion, and make a separate LRFR code summary worksheet
(7) make companion Excel summary form and adjust for direct output
(8) adopt SDG and MBE DF - one lane only, mpf.legal = 1.00
(9) adopt General Method shear capacity for LRFD shallow fills

CHANGE NOTES JULY - JANUARY 2016
(1) edit preficial notes - disclaimer, intent and outline.
(2) update companion summary (Excel) and LRFR code summary

CHANGE NOTES - MARCH 2016
(1) in vehicle list CLVT_VEH_SET(L), row 3 column 2, subrow 2 subcol 1, change "HL93.OPR" to "HS20.OPR."
(2) remove calculations for depth of fill by auto-level; retain this as a separate worksheet
(3) change name from "FDOT OLD CBC" to "FDOT Hinged-End Culvert"
(4) re-arrange order of topics on Page 2
(5) include [quick-start] instructions, top of Page 2
(6) provide slider-bar on Page 6, to select the test vehicle, the vehicle to check on the last 8 pages
(7) move "applicability" section from Page 3 to Page 2
(8) add s.xe < 80in LRFD 8.5.3.4.2-5 (no change for d.v ~ 10in., but makes fidelity to code clearer)
(9) remove 3ksi hard code f.c at exterior wall "a" effective depth of the compression block; substitute with f.c (genuine change)
(10) add "Assumptions, Exterior Wall" section to Page 3
(11) add cartoon examples to Page 3, for inapplicable (frame) and applicable (hinged-end)

Vehicles

$$HS20_FT(L) := \left| \begin{array}{l} SPACING \leftarrow L_1 \cdot (0.6 + 1 + 0.4) \\ SPACING \leftarrow \max\left[14, L_1 \cdot (0.6 + 1 + 0.4)\right] \\ SPACING \leftarrow \min(30, SPACING) \end{array} \right.$$

$$HS20(L) := \left| \begin{array}{l} T \leftarrow \begin{pmatrix} 0 & 8 \\ 14 & 32 \\ 14 & 32 \end{pmatrix} \\ \text{return } T \text{ if } rows(L) < 3 \\ \text{return } T \text{ if } HS20_FT(L) = 14 \\ \begin{bmatrix} T & \begin{pmatrix} 0 & 8 \\ 14 & 32 \\ HS20_FT(L) & 32 \end{pmatrix} \end{bmatrix}^T \end{array} \right.$$

$$HL93(L) := \left| \begin{array}{l} HS20 \leftarrow HS20(L) \\ TAND \leftarrow \begin{pmatrix} 0 & 25 \\ 4 & 25 \end{pmatrix} \\ \text{return } (HS20 \;\; TAND)^T \text{ if } rows(HS20) = 3 \\ stack[HS20, (TAND)] \end{array} \right.$$

$$\begin{pmatrix} SU2 \\ SU3 \\ SU4 \\ ST5 \end{pmatrix} := \begin{bmatrix} \begin{pmatrix} 0 & 12 \\ 13 & 22 \end{pmatrix} \\ \begin{pmatrix} 0 & 22 \\ 11 & 22 \\ 4.17 & 22 \end{pmatrix} \\ \begin{pmatrix} 0 & 13.9 \\ 9.17 & 18.7 \\ 4.17 & 18.7 \\ 4.17 & 18.7 \end{pmatrix} \\ \begin{pmatrix} 0 & 8 \\ 27 & 18 \\ 4 & 18 \\ 12 & 18 \\ 24 & 18 \end{pmatrix} \end{bmatrix} \qquad \begin{pmatrix} C3 \\ C4 \\ C5 \\ FL120 \end{pmatrix} := \begin{bmatrix} \begin{pmatrix} 0 & 12 \\ 10 & 22 \\ 20 & 22 \end{pmatrix} \\ \begin{pmatrix} 0 & 7.3 \\ 10 & 22 \\ 21.83 & 22 \\ 4.17 & 22 \end{pmatrix} \\ \begin{pmatrix} 0 & 10 \\ 10 & 20 \\ 4.17 & 20 \\ 17.67 & 15 \\ 4.17 & 15 \end{pmatrix} \\ \begin{pmatrix} 0 & 13.334 \\ 14 & 53.333 \\ 14 & 53.333 \end{pmatrix} \end{bmatrix}$$

$$CLVT_VEH_SET(L) := \begin{bmatrix} 1 & \begin{pmatrix} \text{"HL93.INV"} & HL93(L) & 1 \\ \text{"HL93.OPR"} & HL93(L) & 2 \\ \text{"FL120"} & FL120 & 4 \\ \text{"SU2"} & SU2 & 3 \\ \text{"SU3"} & SU3 & 3 \\ \text{"SU4"} & SU4 & 3 \\ \text{"C3"} & C3 & 3 \\ \text{"C4"} & C4 & 3 \\ \text{"C5"} & C5 & 3 \\ \text{"ST5"} & ST5 & 3 \end{pmatrix} \\ 1 & \begin{pmatrix} \text{"HL93.INV"} & HL93(L) & 1 \\ \text{"HL93.OPR"} & HL93(L) & 2 \\ \text{"FL120"} & FL120 & 4 \end{pmatrix} \\ 0 & \begin{pmatrix} \text{"HS20.INV"} & HS20(L) & 1 \\ \text{"HS20.OPR"} & HS20(L) & 2 \\ \text{"SU2"} & SU2 & 3 \\ \text{"SU3"} & SU3 & 3 \\ \text{"SU4"} & SU4 & 3 \\ \text{"C3"} & C3 & 3 \\ \text{"C4"} & C4 & 3 \\ \text{"C5"} & C5 & 3 \\ \text{"ST5"} & ST5 & 3 \end{pmatrix} \\ 0 & \begin{pmatrix} \text{"HS20.INV"} & HS20(L) & 1 \\ \text{"HS20.OPR"} & HS20(L) & 2 \end{pmatrix} \\ 1 & \begin{bmatrix} \text{"CUSTM"} & \begin{pmatrix} 0.00 & 12.00 \\ 13.00 & 22.00 \end{pmatrix} & 4 \end{bmatrix} \end{bmatrix}$$

CLVT_VEH_SET(L) - standard vehicle sets
COL 1 = Method. 0 means LFR-Std.Spec.-Load Factor; 1 means LRFR-LRFD
COL 2 = Vehicle descriptions: Name, Trucks, Rating Level
Rating Level: 1 - Design Inventory, 2 - Design Operating, 3 - Legal Operating, 4 - Permit

NOTES
Trucks follow this format (ft spacing, kip axle loading).
No lane loading, for the HL93 (LRFD 3.6.1.3.3).
A vehicle can have one or more trucks (Truck and Tandem).

Dimensions

$$L := \left| \begin{array}{l} \text{for } i \in 1..\text{cells} \\ \quad L_i \leftarrow \left| \begin{array}{ll} 0.5 \cdot t_{ExtWall} + W_c + 0.5 \cdot t_{IntWall} & \text{if } i = 1 \vee i = \text{cells} \\ 0.5 \cdot t_{IntWall} + W_c + 0.5 \cdot t_{IntWall} & \text{otherwise} \end{array} \right. \\ L \cdot ft^{-1} \end{array} \right.$$

$L = \begin{pmatrix} 10.83 \\ 10.83 \\ 10.83 \end{pmatrix}$ - span lengths (feet)

$$\rho := \frac{A_s}{d \cdot 12in}$$

$\rho = 0.0082$ - steel/concrete ratio

$$B_c := t_{ExtWall} + \sum L \cdot ft$$

$B_c = 33.33\,ft$ - out-to-out bridge length parallel to the effective span length

Declare Vehicle Selection, Analysis Method, and Precision

$$D_{fills} := \overrightarrow{\text{round}\left(\frac{D_{fills}}{ft}, 2\right)} \cdot ft$$

$D_{fills} = \begin{pmatrix} 1.90 \\ 2.60 \end{pmatrix} ft$ - round fills to 0.01 ft.; standardize significant figures for check calcs

$$TRUCKS := \left| \begin{array}{l} T1 \leftarrow CLVT_VEH_SET(L)_{VehSet,2} \\ T2(K) \leftarrow \text{if}[\text{cols}(K) = 2, (K), K] \\ \overrightarrow{T2(T1)} \end{array} \right.$$

TRUCKS - select method and vehicles

$$LRFR := CLVT_VEH_SET(1)_{VehSet,1}$$

$LRFR = 1.00$ - method is $Method := (\text{"LFR"} \quad \text{"LRFR"})_{1,LRFR+1} = \text{"LRFR"}$

$$AV := \left| \begin{array}{l} T \leftarrow TRUCKS^{\langle 1 \rangle} \\ \text{augment}(\text{matrix}(\text{rows}(T), 1, f(i,j) \leftarrow i + 1), T) \end{array} \right.$$

$$AV^T = \begin{pmatrix} 1.00 & 2.00 & 3.00 & 4.00 & 5.00 & 6.00 & 7.00 & 8.00 & 9.00 & 10.00 \\ \text{"HL93.INV"} & \text{"HL93.OPR"} & \text{"FL120"} & \text{"SU2"} & \text{"SU3"} & \text{"SU4"} & \text{"C3"} & \text{"C4"} & \text{"C5"} & \text{"ST5"} \end{pmatrix}$$

select the test vehicle :

$testVEH = 2.00$ - check this vehicle, last 8 pages: $AV_{testVEH,2} = \text{"HL93.OPR"}$

$ips := 40$

$ips = 40$ - precision, increments per span (10 is OK, 20 is good, and 40 is best)

$ips_{LL} := 100$

$ips_{LL} = 100$ - increments of truck travel (20 is OK, 50 is good, and 100 is best)

$$d_{AFF} := \left| \begin{array}{ll} 0.5 \cdot t_{ExtWall} + d & \text{if cells} = 1 \\ 0.5 \cdot t_{IntWall} + d & \text{otherwise} \end{array} \right.$$

$d_{AFF} = 1.14\,ft$ - distance CL of bearing to "d" away from face, for shear RF location

Load Factors

$$\gamma_{LL_MAT} := \begin{pmatrix} \text{"VEH TYPE"} & \text{"}\gamma\text{DESC"} & \text{"}\gamma\text{.LF"} & \text{"}\gamma\text{.LRFD"} \\ 1 & \text{"}\gamma\text{.INV "} & 2.17 & 1.75 \\ 2 & \text{"}\gamma\text{.OPR "} & 1.30 & 1.35 \\ 3 & \text{"}\gamma\text{.OPR "} & 1.30 & 1.35 \\ 4 & \text{"}\gamma\text{.PERM"} & 1.30 & 1.35 \end{pmatrix}$$

γ_{LL_MAT} - live load factor matrix (BLRM Tables 6A.5.12.5-1 & 6B.5.3)

$\gamma_{LLmin} := (1 \quad 0)_{1,LRFR+1}$

$\gamma_{LLmin} = 0.00$ - for LFR, apply all effects; for LRFR, apply extreme effects

$veh_type(iv) := TRUCKS_{iv,3}$

$veh_type(iv)$ - vehicle type equation (1=Des.INV, 2=Des.OPR, 3=Legal.OPR, 4=PERMIT)

$mpf_eq(iv) := if(LRFR = 1 \wedge veh_type(iv) < 3, 1.20, 1.00)$

$mpf_eq(iv)$ - single lane multiple presence factor equation

$\gamma LL_eq(iv) := \gamma_{LL_MAT_{veh_type(iv)+1,3+LRFR}}$

$\gamma LL_eq(iv)$ - live load factor equation

$\gamma_{LL} := \overrightarrow{\gamma LL_eq\left(AV^{\langle 1 \rangle}\right)} \qquad mpf := \overrightarrow{mpf_eq\left(AV^{\langle 1 \rangle}\right)}$

γ_{LL} - live load factors, vector for all vehicles

$$AV2 := \left| \begin{array}{l} (LBL \quad Nos) \leftarrow \left[(\text{"\#"} \quad \text{"VEH"} \quad \text{"TYPE"} \quad \text{"mpf"} \quad \text{"}\gamma\text{.LL"}) \quad AV^{\langle 1 \rangle} \right] \\ DAT \leftarrow augment\left(AV, \overrightarrow{veh_type(Nos)}, \overrightarrow{mpf_eq(Nos)}, \overrightarrow{\gamma LL_eq(Nos)}\right) \\ stack(LBL, DAT) \end{array} \right.$$

- available vehicles: No., name, type No., mpf, γ.LL

$AV3 := augment\left(AV2^{\langle 2 \rangle}, AV2^{\langle 4 \rangle}, AV2^{\langle 5 \rangle}\right)$

AV3 - available vehicles: name, mpf, γ.LL

$$AV2 = \begin{pmatrix} \text{"\#"} & \text{"VEH"} & \text{"TYPE"} & \text{"mpf"} & \text{"}\gamma\text{.LL"} \\ 1.00 & \text{"HL93.INV"} & 1.00 & 1.20 & 1.75 \\ 2.00 & \text{"HL93.OPR"} & 2.00 & 1.20 & 1.35 \\ 3.00 & \text{"FL120"} & 4.00 & 1.00 & 1.35 \\ 4.00 & \text{"SU2"} & 3.00 & 1.00 & 1.35 \\ 5.00 & \text{"SU3"} & 3.00 & 1.00 & 1.35 \\ 6.00 & \text{"SU4"} & 3.00 & 1.00 & 1.35 \\ 7.00 & \text{"C3"} & 3.00 & 1.00 & 1.35 \\ 8.00 & \text{"C4"} & 3.00 & 1.00 & 1.35 \\ 9.00 & \text{"C5"} & 3.00 & 1.00 & 1.35 \\ 10.00 & \text{"ST5"} & 3.00 & 1.00 & 1.35 \end{pmatrix}$$

Dead Load

$$\begin{pmatrix} \gamma_{DCmin} \\ \gamma_{DCmax} \\ \eta\gamma_{EVmin} \\ \eta\gamma_{EVmax} \\ \eta\gamma_{EHmin} \\ \eta\gamma_{EHmax} \end{pmatrix} := \begin{pmatrix} 1.30 & 0.90 \\ 1.30 & 1.25 \\ 1.30 & 1.00\cdot 0.90 \\ 1.30 & 1.05\cdot 1.30 \\ 0.50\cdot 1.30 & 1.00\cdot 0.90 \\ 1.30 & 1.05\cdot 1.35 \end{pmatrix}^{\langle LRFR+1 \rangle}$$

$$\begin{pmatrix} \gamma_{DCmin} \\ \gamma_{DCmax} \\ \eta\gamma_{EVmin} \\ \eta\gamma_{EVmax} \\ \eta\gamma_{EHmin} \\ \eta\gamma_{EHmax} \end{pmatrix} = \begin{pmatrix} 0.90 \\ 1.25 \\ 0.90 \\ 1.37 \\ 0.90 \\ 1.42 \end{pmatrix}$$ Load factors (Std.Spec. 3.22.1.A, BLRM 6A.5.12.5-1)

$\omega_{DC} := 150pcf \cdot 12in \cdot t_{slab}$

$\omega_{DC} = 0.128 \cdot klf$ - component/slab load (SDG 3.15.4)

$\gamma_{soil} := 120pcf$

$\gamma_{soil} = 120 \cdot pcf$ - unit weight of soil (SDG 3.15.4)

$F_{e.eq}(D) := \min\left(1.15, 1 + 0.20 \cdot \frac{D}{B_c}\right)$

$\overrightarrow{F_{e.eq}(D_{fills})} = \begin{pmatrix} 1.011 \\ 1.016 \end{pmatrix}$ - soil interaction factor (Std.Spec.Eq. 16-16, LRFD 12.11.2.2.1-2)

$\omega_{EV}(D) := F_{e.eq}(D) \cdot D \cdot \gamma_{soil} \cdot ft$

$\overrightarrow{\omega_{EV}(D_{fills})} = \begin{pmatrix} 0.231 \\ 0.317 \end{pmatrix} \cdot klf$ - vertical earth loading

$\omega_{EH}(D) := \frac{\gamma_{soil}}{2} \cdot D \cdot ft$

$\overrightarrow{\omega_{EH}(D_{fills})} = \begin{pmatrix} 0.114 \\ 0.156 \end{pmatrix} \cdot klf$ - lateral earth pressure

$\omega_{DL}(D) := \left(\omega_{DC} + \omega_{EV}(D)\right) \cdot klf^{-1}$

$\overrightarrow{\omega_{DL}(D_{fills})} = \begin{pmatrix} 0.359 \\ 0.445 \end{pmatrix}$ - total unfactored vertical DL (klf)

Top Slab, Distribution & Impact (1 of 2)

LATERAL DISTRIBUTION

$LRFR = 1.00$ Method = "LRFR"

$gage := 6ft$ gage - gage width, spacing between wheel lines (BLRM Appendix)

$lane_w := 12ft$ $lane_w$ - lane width (Std.Spec.17th Ed. Fig. 3.7.A, LRFD Fig. 3.6.1.2.2-1)

$tire_{width} := if(LRFR = 0, 0, 20in + 0.06 \cdot W_c)$ $tire_{width} = 27.20 \cdot in$ - tire width (Std.Spec.6.4.1, LRFD 3.6.1.2.6b)

$tire_{length} := if(LRFR = 0, 0, 10in)$ $tire_{length} = 10.00 \cdot in$ - tire length (Std.Spec. 3.30, LRFD 3.6.1.2.5)

$DF_{earth} := if(LRFR = 0, 1.75, 1.15)$ $DF_{earth} = 1.15$ distribution, earth (Std.Spec.17th Ed. 6.4.1, LRFD Table 3.6.1.2.6a-1)

Eeq(mpf_1LANE, D_fill) - equivalent strip width for lateral distribution. mpf_1LANE - single-lane multiple presence factor, D - covering fill, from the roadway surface to the top of the top slab, (Slab distribution from Std.Spec. 3.24.3.2 & LRFD Eq. 4.6.2.10.2-1. Earth distribution from Std.Spec. 6.4 & LRFD 3.6.1.2.6). For effective span length, say clear span (Std.Spec. 3.24.1.1 & LRFD 4.6.2.10.2-1).

$$Eeq(mpf_1LANE, D_{fill}) := \left| \begin{array}{l} E_SLAB \leftarrow 8ft + 0.12 \cdot W_c \\ E_EARTH_1TRUCK \leftarrow \min\left[2 \cdot \left(tire_{width} + D_{fill} \cdot DF_{earth}\right), 1 \cdot \left(tire_{width} + DF_{earth} \cdot D_{fill} + gage\right)\right] \\ E_EARTH_2TRUCKS \leftarrow \min\left[1 \cdot \left(tire_{width} + D_{fill} \cdot DF_{earth} + 4ft\right), 0.5 \cdot \left(tire_{width} + D_{fill} \cdot DF_{earth} + 2 \cdot gage + 4ft\right)\right] \\ \begin{pmatrix} \max\left(\frac{E_SLAB}{1.00}, \min\left(\frac{E_EARTH_1TRUCK}{1.00}, \frac{E_EARTH_2TRUCKS}{1.00}\right)\right) \\ \max\left(\frac{E_SLAB}{mpf_1LANE}, \min\left(\frac{E_EARTH_1TRUCK}{mpf_1LANE}\right)\right) \end{pmatrix}_{LRFR+1} \end{array} \right.$$

$$E(D_{fill}) := \left| \begin{array}{l} T \leftarrow \left(concat\left("D.fill =", num2str\left(D_{fill} \cdot ft^{-1}\right), "ft"\right) \quad "mpf, 1\ lane" \quad "E\ (ft)"\right) \\ return\ stack\left[T, \left("INV/OPR" \quad 1 \quad Eeq\left(1, D_{fill}\right) \cdot ft^{-1}\right)\right] \ \ if\ LRFR = 0 \\ return\ stack\left[T, \begin{pmatrix} "HL93" & 1.2 & Eeq\left(1.2, D_{fill}\right) \cdot ft^{-1} \\ "LGL/FL120" & 1 & Eeq\left(1, D_{fill}\right) \cdot ft^{-1} \end{pmatrix}\right] \ \ if\ LRFR = 1 \end{array} \right.$$

$$\overrightarrow{E(D_{fills})} = \begin{bmatrix} \begin{pmatrix} "D.fill =1.9ft" & "mpf, 1\ lane" & "E\ (ft)" \\ "HL93" & 1.20 & 7.67 \\ "LGL/FL120" & 1.00 & 9.20 \end{pmatrix} \\ \begin{pmatrix} "D.fill =2.6ft" & "mpf, 1\ lane" & "E\ (ft)" \\ "HL93" & 1.20 & 8.76 \\ "LGL/FL120" & 1.00 & 10.51 \end{pmatrix} \end{bmatrix}$$

$$LLDFeq(mpf_1LANE, D_{fill}) := \frac{ft}{Eeq(mpf_1LANE, D_{fill})}$$

LLDFeq(mpf_1LANE, D_fill) - lateral distribution factor (axles per 1 foot strip)

LONGITUDINAL DISTRIBUTION THROUGH FILL

$E_{long.eq}(D) := DF_{earth} \cdot D + tire_{length}$ $E_{long}(D)$ - longitudinal distribution length (Std.Spec. 1.1.1 & 6.4.1, LRFD 4.6.2.10.2-2)

IMPACT

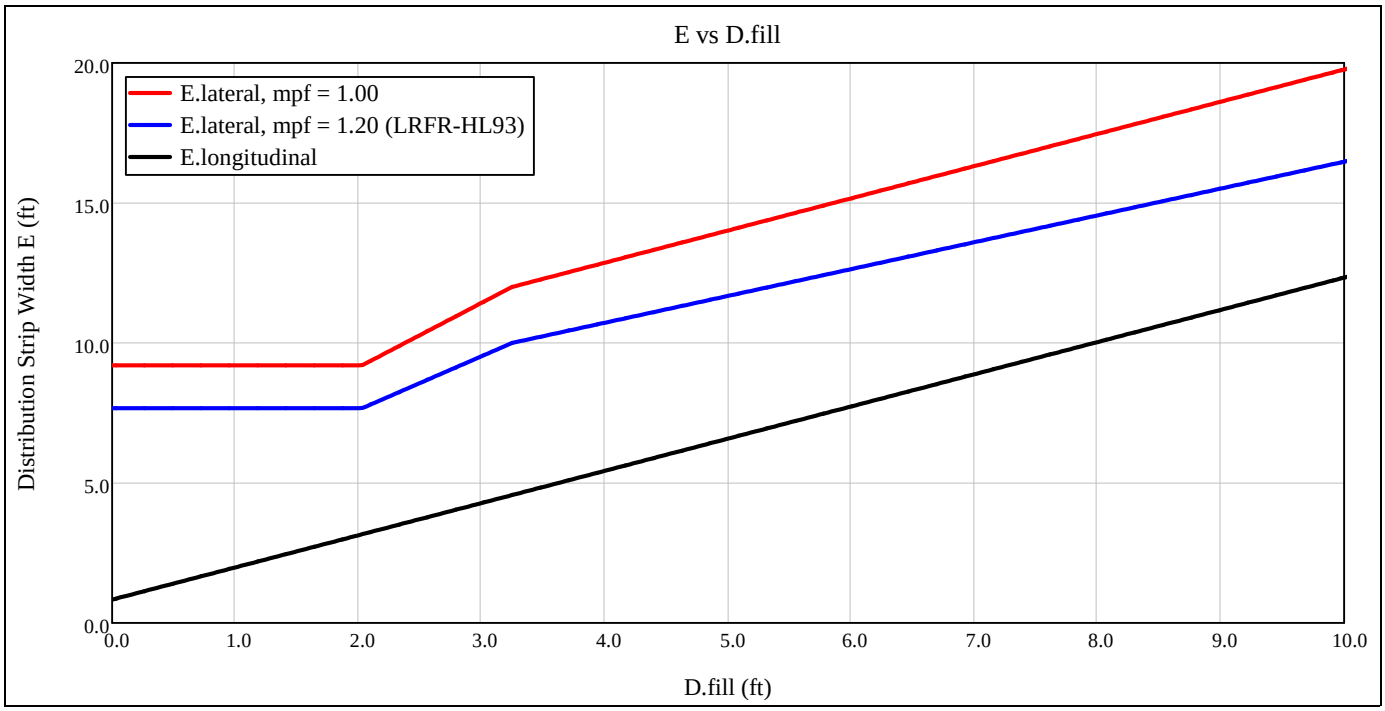
LRFR = 1.00 Method = "LRFR"

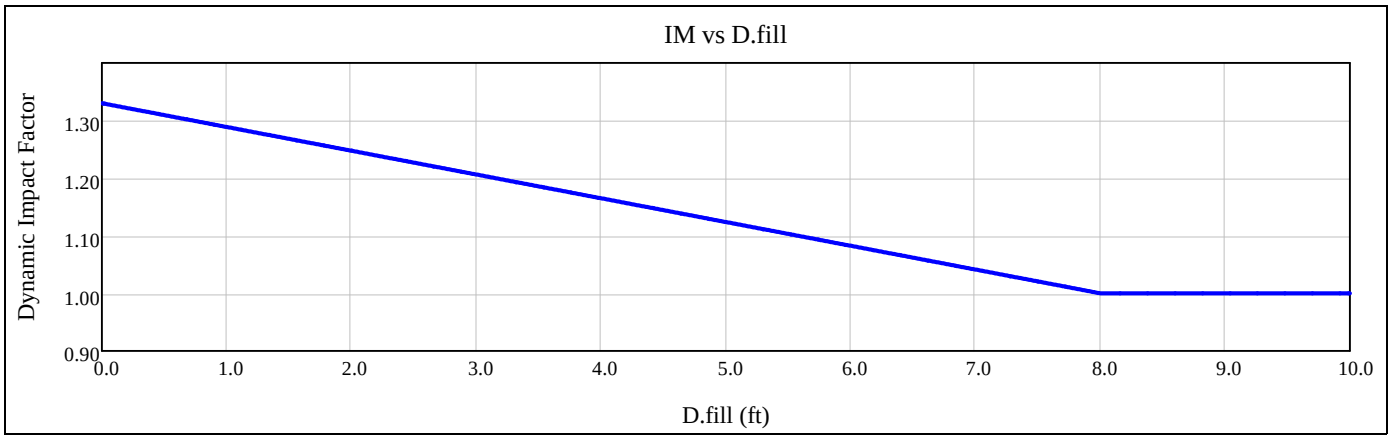
$$IM_{CLVT.Std.Spec.} := \begin{pmatrix} 0 & 1 & 1 & 2 & 2 & 3 & 3 & 20 \\ 1.3 & 1.3 & 1.2 & 1.2 & 1.1 & 1.1 & 1 & 1 \end{pmatrix}^T$$

$IM_{CLVT.Std.Spec.}$ - plot points, step-wise LFR impact(Std.Spec. 3.8.2.3)

$$IMeq(D_{fill}) := \begin{cases} \text{if } LRFR = 0 \\ \quad IM \leftarrow \min\left[1.30, 1.30 - \frac{0.30}{3}\cdot\left(\frac{D_{fill}}{ft} - 0.5\right)\right] \\ \quad \max(1.00, IM) \\ \text{if } LRFR = 1 \\ \quad IM \leftarrow \min\left[1.33, 1 + 0.33\cdot\left(1 - \frac{D_{fill}}{8ft}\right)\right] \\ \quad \max(1.00, IM) \end{cases}$$

$IMeq(D_{fill})$ - live load impact (Std.Spec. 3.8.2.3 interpolated, LRFD 3.6.2.2-1)





Top Slab, Make Influence Table (1 of 8)

match2(n, M) - for exact match

$$\text{match2}(n, M) := \text{match}\left(n \cdot 10^{10}, M \cdot 10^{10}\right)_{1,1}$$

Vinc - shear check location at d away from face of bearing at Pier 2

$$\text{Vinc} := \min\left[1.999, \left(L_1 - \frac{d_{AFF}}{ft}\right) \cdot \left(L_1\right)^{-1} + 1\right] = 1.90$$

BrIncs_{eq1} BrIncs_{eq2} & BrIncs - bridge increments: span No. + % span length

$$\text{BrIncs}_{eq1}(L, ips) := \left| \begin{array}{l} r \leftarrow 0 \\ \text{for } \text{SpanNo} \in 1..\text{rows}(L) \\ \quad \text{for } i \in 1..ips + 1 \\ \quad\quad \left| \begin{array}{l} \text{row} \leftarrow i + (ips + 1) \cdot (\text{SpanNo} - 1) \\ T2 \leftarrow \left| \begin{array}{ll} (i - 1) + 10^{-9} & \text{if } i = 1 \\ i - 1 & \text{if } i > 1 \wedge i < ips + 1 \\ (i - 1) - 10^{-9} & \text{if } i = ips + 1 \end{array} \right. \\ r \leftarrow r + 1 \\ T1_r \leftarrow \text{SpanNo} + \dfrac{T2}{ips} \end{array} \right. \\ T1 \end{array} \right.$$

$$\text{BrIncs}_{eq2}(L, ips) := \left| \begin{array}{l} \text{BrINCS} \leftarrow \text{csort}\left[\text{stack}\left[\begin{pmatrix} \text{Vinc} - 0.0001 \\ \text{Vinc} \\ \text{Vinc} + 0.0001 \end{pmatrix}, \text{BrIncs}_{eq1}(L, ips)\right], 1\right] \\ T \leftarrow \left(\text{BrINCS}_1\right) \\ \text{for } i \in 2..\text{rows}(\text{BrINCS}) \\ \quad T \leftarrow \text{if}\left(\text{BrINCS}_{i-1} = \text{BrINCS}_i, T, \text{stack}\left(T, \text{BrINCS}_i\right)\right) \\ T \end{array} \right.$$

$$\text{BrIncs} := \text{BrIncs}_{eq2}(L, ips)$$

RSIF_{eq} & RSIF - influence locations: (R)ow, (S)pan, (I)ncrement, (F)eet

$$\text{RSIF}_{eq}(L, \text{BrIncs}) := \left| \begin{array}{l} Lt \leftarrow \text{stack}[(0), L] \\ \text{for } i \in 1..\text{rows}(\text{BrIncs}) \\ \quad \left| \begin{array}{l} \text{span} \leftarrow \text{trunc}\left(\text{BrIncs}_i\right) \\ ft \leftarrow \left(\displaystyle\sum_{k=1}^{\text{span}} Lt_k\right) + \left[L_{\text{span}} \cdot \left(\text{BrIncs}_i - \text{span}\right)\right] \\ T^{\langle i \rangle} \leftarrow \left(i + 1 \quad \text{span} \quad \text{BrIncs}_i \quad ft\right)^T \end{array} \right. \\ T \leftarrow T^T \\ T2 \leftarrow \begin{bmatrix} 1 & \text{rows}(T) + 2 \\ 0 & \text{rows}(L) + 1 \\ \left(1 - \dfrac{0.001}{L_1}\right) & \left(\text{rows}(L) + 1 + \dfrac{0.001}{L_{\text{rows}(L)}}\right) \\ -0.001 \cdot L_1 & \sum L + 0.001 \cdot L_1 \end{bmatrix}^T \\ T \leftarrow \text{stack}(T, T2) \\ \text{csort}(T, 1) \end{array} \right.$$

$$\text{RSIF} := \text{RSIF}_{eq}(L, \text{BrIncs})$$

Top Slab, Make Influence Table (2 of 8)

RSIF_CHK_LOCS - check locations: (R)ow, (S)pan, (I)ncrement, (F)eet

$$RSIF_CHK_LOCS := \left| \begin{array}{l} r(BrINC) \leftarrow match2\left(BrINC, RSIF^{\langle 3 \rangle}\right) \\ Get \leftarrow \left(\begin{array}{c} match2\left(\left| \begin{array}{l} 1.50 \ \text{ if } \ cells = 1 \\ 1.40 \ \text{ otherwise} \end{array} \right. , RSIF^{\langle 3 \rangle} \right) \\ match\left(2.00, RSIF^{\langle 3 \rangle}\right)_1 \\ match2\left(Vinc, RSIF^{\langle 3 \rangle}\right) \\ match2\left(Vinc, RSIF^{\langle 3 \rangle}\right) \end{array} \right) \\ \text{for } \ i \in 1..rows(Get) \\ \quad T2^{\langle i \rangle} \leftarrow \left(RSIF^{T}\right)^{\langle \left(Get_i\right) \rangle} \\ T2^{T} \end{array} \right.$$

$$\left| \begin{array}{l} HDR \leftarrow (\text{"ROW"} \ \ \text{"SPAN"} \ \ \text{"INC"} \ \ \text{"FT"}) \\ stack(HDR, RSIF_CHK_LOCS) \end{array} \right. = \begin{pmatrix} \text{"ROW"} & \text{"SPAN"} & \text{"INC"} & \text{"FT"} \\ 18.00 & 1.00 & 1.40 & 4.33 \\ 45.00 & 1.00 & 2.00 & 10.83 \\ 39.00 & 1.00 & 1.90 & 9.70 \\ 39.00 & 1.00 & 1.90 & 9.70 \end{pmatrix}$$

pM_{BrINC} - positive moment location

$$pM_{BrINC} := RSIF_{RSIF_CHK_LOCS_{1,1},3} = 1.40$$

pier location

$$SUML(L) := \left| \begin{array}{l} \text{for } \ i \in 1..rows(L) \\ \quad SUML_i \leftarrow \sum_{k=1}^{i} L_k \\ SUML \end{array} \right.$$

bridge length

$$ENDPIER(L) := \sum L$$

is x over a pier?

$$axlatpier(x, L) := \left| \begin{array}{l} T_1 \leftarrow 1 \ \text{ if } \ x = 0 \\ T_1 \leftarrow 0 \ \text{ otherwise} \\ \text{for } \ i \in 1..rows(L) \\ \quad \left| \begin{array}{l} T_{i+1} \leftarrow i + 1 \ \text{ if } \ x = \sum_{k=1}^{i} L_k \\ T_{i+1} \leftarrow 0 \ \text{ otherwise} \end{array} \right. \\ max(T) \end{array} \right.$$

x is in what span?

$$axlspan(x, L) := \left| \begin{array}{l} T \leftarrow 0 \ \text{ if } \ x < 0 \vee x > ENDPIER(L) \\ \text{otherwise} \\ \quad \left| \begin{array}{l} T \leftarrow 1 \\ \text{while } \ \dfrac{x}{\sum_{k=1}^{T} L_k} > 1 \\ \quad T \leftarrow T + 1 \end{array} \right. \\ rows(L) + 1 \ \text{ if } \ x = \sum_{k=1}^{rows(L)} L_k \\ T \ \text{ otherwise} \end{array} \right.$$

local distance to nearest left pier

$$a(x, L) := \left| \begin{array}{l} x \ \text{ if } \ axlspan(x, L) = 1 \vee rows(L) = 1 \\ x - \sum_{k=1}^{axlspan(x,L)-1} L_k \ \text{ otherwise} \end{array} \right.$$

EI - stiffness

$$EI := 10 \cdot 10^4$$

Top Slab, Make Influence Table (3 of 8)

what's the sign of theta?

$$\text{signtheta}(x,L) := \begin{cases} 1 & \text{if } \text{round}\left(\frac{\text{axlspan}(x,L)}{2},0\right) = 0 \\ -1 & \text{otherwise} \end{cases}$$

simple moment

$$MP(x,L) := \begin{cases} \text{spanNo} \leftarrow \text{axlspan}(x,L) \\ \frac{L_{\text{spanNo}} - a(x,L)}{L_{\text{spanNo}}} \cdot a(x,L) \end{cases}$$

MEQ1 - unknown θ.1 & areas of moments

$$MEQ1p(x,L) := \begin{cases} \text{for } i \in 1..\text{rows}(L) \\ \quad T_{i,1} \leftarrow \text{signtheta}(x,L) \cdot EI \cdot (-1) \\ \text{for } i \in 1..\text{rows}(L) \\ \quad \begin{cases} 0 & \text{if } \text{rows}(L) = 1 \\ \text{otherwise} \\ \quad \text{for } j \in 2..\text{rows}(L) \\ \quad\quad T_{i,j} \leftarrow \begin{cases} 0 & \text{if } j > i \\ \text{otherwise} \\ \quad \begin{cases} 0.5 \cdot L_{j-1} & \text{if } j = i \\ 0.5 \cdot \left(L_{j-1} + L_j\right) & \text{otherwise} \end{cases} \end{cases} \\ \quad\quad T \end{cases} \\ T \end{cases}$$

MEQ2 - unknown area moments * known distance

$$MEQ2p(x,L) := \begin{cases} \text{for } i \in 1..\text{rows}(L) \\ \quad \text{for } j \in 1..\text{rows}(L) \\ \quad\quad \begin{cases} \text{if } i = 1 \\ \quad \begin{cases} AM_{i,j} \leftarrow \frac{L_i}{6} & \text{if } j = 2 \\ AM_{i,j} \leftarrow 0 & \text{otherwise} \end{cases} \\ \text{otherwise} \\ \quad \begin{cases} AM_{i,j} \leftarrow \frac{L_i}{6} & \text{if } j = i + 1 \\ \text{otherwise} \\ \quad \begin{cases} AM_{i,j} \leftarrow \frac{L_i}{3} & \text{if } j = i \\ AM_{i,j} \leftarrow 0 & \text{otherwise} \end{cases} \end{cases} \end{cases} \\ AM \end{cases}$$

MEQ3p(x,L) - sum unknowns

$$MEQSUMp(x,L) := MEQ1p(x,L) + MEQ2p(x,L)$$

MEQ3ap - known simple point load area

$$MEQ3ap(x,L) := \begin{cases} T_{1,1} \leftarrow 0 & \text{if } \text{rows}(L) = 1 \\ \text{otherwise} \\ \quad \begin{cases} \text{row} \leftarrow \text{axlspan}(x,L) \\ \text{for } i \in 1..\text{rows}(L) \\ \quad \begin{cases} T_{i,1} \leftarrow \frac{L_{\text{row}}}{2} & \text{if } \text{row} < i \\ T_{i,1} \leftarrow -0 & \text{otherwise} \end{cases} \\ T \end{cases} \\ T \end{cases}$$

MEQbp - known simple point load moment

$$MEQ3bp(x,L) := \begin{cases} \text{for } i \in 1..\text{rows}(L) \\ \quad T_{i,1} \leftarrow 0 \\ \text{row} \leftarrow \text{axlspan}(x,L) \\ T_{\text{row},1} \leftarrow \frac{L_{\text{row}}}{3} - \frac{a(x,L)}{6} \\ T \end{cases}$$

MEQ3p(x,L) - sum knowns, and multiply by point moment

$$MEQ3p(x,L) := (MEQ3ap(x,L) + MEQ3bp(x,L)) \cdot MP(x,L) \cdot \text{signtheta}(x,L)$$

Top Slab, Make Influence Table (4 of 8)

MeqGO(x, L) whether moment solution can run

$$\text{MeqGO}(x,L) := \begin{cases} 0 & \text{if } x \le 0 \vee x \ge \text{ENDPIER}(L) \\ 1 & \text{otherwise} \end{cases}$$

SOLNp(x, L) - theta, pier moments

$$\text{SOLNp}(x,L) := \begin{cases} \text{if } \text{MeqGO}(x,L) = 0 \\ \quad \begin{cases} \text{for } i \in 1..\text{rows}(L) \\ \quad T_i \leftarrow 0 \\ T \end{cases} \\ \text{MEQSUMp}(x,L)^{-1} \cdot \text{MEQ3p}(x,L) \quad \text{otherwise} \end{cases}$$

axlspanpier(x, L) - get span No. if on endpier, report last span. else if on pier, report pier no.

$$\text{axlspanpier}(x,L) := \begin{cases} \text{SPA} \leftarrow \text{axlspan}(x,L) \\ \text{PIER} \leftarrow \text{axlatpier}(x,L) \\ \min(\text{rows}(L), \max(\text{SPA}, \text{PIER})) \end{cases}$$

ReturnAXLonPIER(xaxl, L, xtst, OnPier, span) - if the axle is on a pier, report influence (M,V+,V-)

$$\text{ReturnAXLonPIER}(\text{xaxl}, L, \text{xtst}, \text{OnPier}, \text{span}) := \begin{cases} \text{return} \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} & \text{if } \text{OnPier} = 1 \wedge \text{xaxl} = \text{xtst} = 0 \\ \text{return} \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} & \text{if } \text{OnPier} = \text{span} \wedge \text{xaxl} = \text{xtst} \\ \text{return} \begin{pmatrix} 0 \\ 0 \\ -1 \end{pmatrix} & \text{if } \text{OnPier} = \text{span} + 1 \wedge \text{xaxl} = \text{xtst} \\ \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix} \end{cases}$$

$R3_{local}(xaxl, L, xtst)$ - simple span influence (moment, positive shear, negative shear) at xtst span, from 1 kip load at xaxl)

$$R3_{local}(xaxl, L, xtst, span) := \left| \begin{array}{l}
SPANnoAXL \leftarrow axlspanpier(xaxl, L) \\
SPANnoTST \leftarrow span \\
\text{return} \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix} \text{ if } SPANnoAXL \neq SPANnoTST \vee SPANnoTST = 0 \\
XlocAXL \leftarrow \left| \begin{array}{ll} xaxl \text{ if } SPANnoAXL = 1 & \\ xaxl - SUML(L)_{SPANnoAXL-1} & \text{otherwise} \end{array} \right. \\
XlocTST \leftarrow \left| \begin{array}{ll} xtst \text{ if } SPANnoTST = 1 & \\ xtst - SUML(L)_{SPANnoTST-1} & \text{otherwise} \end{array} \right. \\
R_{left} \leftarrow \dfrac{L_{SPANnoAXL} - XlocAXL}{L_{SPANnoAXL}} \\
R_{right} \leftarrow \dfrac{XlocAXL}{L_{SPANnoAXL}} \\
\text{if } XlocTST < XlocAXL \\
\quad \left| \begin{array}{l} M_{local} \leftarrow XlocTST \cdot R_{left} \\ V_{local_pos} \leftarrow R_{left} \\ V_{local_neg} \leftarrow R_{left} \end{array} \right. \\
\text{if } XlocTST > XlocAXL \\
\quad \left| \begin{array}{l} M_{local} \leftarrow \left(L_{SPANnoAXL} - XlocTST\right) \cdot R_{right} \\ V_{local_pos} \leftarrow -R_{right} \\ V_{local_neg} \leftarrow -R_{right} \end{array} \right. \\
\text{if } XlocTST = XlocAXL \\
\quad \left| \begin{array}{l} M_{local} \leftarrow XlocTST \cdot R_{left} \\ V_{local_pos} \leftarrow R_{left} \\ V_{local_neg} \leftarrow -R_{right} \end{array} \right. \\
\begin{pmatrix} M_{local} \\ V_{local_pos} \\ V_{local_neg} \end{pmatrix}
\end{array} \right.$$

Top Slab, Make Influence Table (6 of 8)

R3a(xaxl, L, xtst, span) - get simple and pier influence

$$
\begin{aligned}
&R3a\left(L, T_{SOLNp}, xtst, span\right) := \\
&\quad SPANnoTST \leftarrow span \\
&\quad \text{return } (0\ \ 0\ \ 0)^T \ \text{ if } SPANnoTST < 1 \vee SPANnoTST > rows(L) \\
&\quad XlocTST \leftarrow \begin{cases} xtst & \text{if } SPANnoTST = 1 \\ xtst - SUML(L)_{SPANnoTST-1} & \text{otherwise} \end{cases} \\
&\quad \left(M_{left}\ \ M_{right}\ \ V_{pier}\right) \leftarrow (0\ \ 0\ \ 0) \\
&\quad \text{return} \ \ \text{if } SPANnoTST = 1 \\
&\qquad M_{right} \leftarrow T_{SOLNp_2} \cdot \frac{XlocTST}{L_1} \\
&\qquad V_{pier} \leftarrow \left(\frac{T_{SOLNp_2}}{L_1}\right) \\
&\qquad \left[\left(M_{left} + M_{right}\right)\ \ V_{pier}\ \ V_{pier}\right]^T \\
&\quad \text{return} \ \ \text{if } SPANnoTST \geq rows(L) \\
&\qquad M_{right} \leftarrow 0 \\
&\qquad Ltemp \leftarrow L_{rows(L)} \\
&\qquad T \leftarrow \begin{cases} 0 & \text{if } SPANnoTST = rows(L) + 1 \\ 1 & \text{otherwise} \end{cases} \\
&\qquad M_{left} \leftarrow T_{SOLNp_{rows(L)}} \cdot \left(1 - \frac{XlocTST}{Ltemp}\right) \cdot T \\
&\qquad V_{pier} \leftarrow -\left(\frac{T_{SOLNp_{rows(L)}}}{Ltemp}\right) \\
&\qquad \left[\left(M_{left} + M_{right}\right)\ \ V_{pier}\ \ V_{pier}\right]^T \\
&\quad \text{return} \ \ \text{if } 1 < SPANnoTST < rows(L) \\
&\qquad M_{left} \leftarrow T_{SOLNp_{(SPANnoTST)}} \cdot \left(1 - \frac{XlocTST}{L_{SPANnoTST}}\right) \\
&\qquad M_{right} \leftarrow T_{SOLNp_{(SPANnoTST+1)}} \cdot \left(\frac{XlocTST}{L_{SPANnoTST}}\right) \\
&\qquad V_{pier} \leftarrow \frac{-T_{SOLNp_{(SPANnoTST)}} + T_{SOLNp_{(SPANnoTST+1)}}}{L_{SPANnoTST}} \\
&\qquad \left[\left(M_{left} + M_{right}\right)\ \ V_{pier}\ \ V_{pier}\right]^T
\end{aligned}
$$

MVVa(L, xaxl, xtst, span, SLN) - if 1 span, use simple solution; otherwise use continuous

$$
\begin{aligned}
&MVVa(L, xaxl, xtst, span, SLN) := \\
&\quad R3local \leftarrow R3_{local}(xaxl, L, xtst, span) \\
&\quad \text{return } R3local \ \text{ if } rows(L) = 1 \\
&\quad R3a(L, SLN, xtst, span) + R3local
\end{aligned}
$$

MVVb(xaxl, xtst) - get +M +V -V for one test location and one axle location

$$
\begin{aligned}
&MVVb(xaxl, xtst) := \\
&\quad span \leftarrow axlspan(xtst, L) \\
&\quad SLN \leftarrow SOLNp(xaxl, L) \\
&\quad MVVa(L, xaxl, xtst, span, SLN)
\end{aligned}
$$

Top Slab, Make Influence Table (7 of 8)

R4(xaxl, L) - influence (+M, +V, -V) from 1kip load at location xaxl in bridge feet, when RSIF (bridge geometry matrix) is known.

```
R4(xaxl, L, RSIF) := | SLN ← SOLNp(xaxl, L)
                     | MVV(xtst, span) ← MVVa(L, xaxl, xtst, span, SLN)
                     | for j ∈ 1..rows(RSIF)
                     |   | (span  xtst) ← (RSIF[j,2  RSIF[j,4])
                     |   | T⟨j⟩ ← MVV(xtst, span)
                     |   | T⟨j⟩ ← (0  0  0)^T  if xtst < 0 ∨ xtst > Σ L
                     | T
```

$INF2_{eq}$ & INF2 - - regular influence table (+M, -M, +V, -V)

```
INF2eq(L, RSIF) := | for i ∈ 1..rows(RSIF)
                   |   | T ← R4(RSIF[i,4], L, RSIF)^T
                   |   | (M⟨i⟩  Vp⟨i⟩  Vn⟨i⟩) ← (T⟨1⟩  T⟨2⟩  T⟨3⟩)
                   | (M^T  M^T  Vp^T  Vn^T)
```

```
INF2 := INF2eq(L, RSIF)
```

INF_{show} - an abbreviated influence matrix, with few increments, for display.

```
INFshow := | L ← L
           | ips ← 5
           | RSIF ← RSIFeq(L, BrIncseq2(L, ips))
           | S(r) ← matrix(r, 1, f(i, j) ← "")
           | I ← INF2eq(L, RSIF)
           | SIDE ← stack[("#"  "SPAN"  "BrINC"  "FT"), RSIF]
           | DAT ← augment(diag(I[1,3]), diag(I[1,4]), I[1,1])
           | LBL ← ("V+"  "V-")
           | HDR ← augment(LBL, RSIF⟨3⟩^T)
           | T ← augment(SIDE, stack(HDR, DAT))
```

ABBREVIATED INFLUENCE TABLE , FOR CHECKING

#	SPAN	BrINC	FT	V+	V-	0.9999	1.0000	1.2000	1.4000	1.6000	1.8000	1.8951	1.8952	1.8953	2.0000
1	0	**1.00**	0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	1	**1.00**	0.0	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	1	**1.20**	2.2	0.7488	-0.2512	0.0000	0.0000	1.6224	1.0781	0.5339	-0.0104	-0.2692	-0.2695	-0.2697	-0.5547
4	1	**1.40**	4.3	0.5104	-0.4896	0.0000	0.0000	1.1059	2.2117	1.1509	0.0901	-0.4142	-0.4148	-0.4153	-0.9707
5	1	**1.60**	6.5	0.2976	-0.7024	0.0000	0.0000	0.6448	1.2896	1.9344	0.4125	-0.3111	-0.3118	-0.3126	-1.1093
6	1	**1.80**	8.7	0.1232	-0.8768	0.0000	0.0000	0.2669	0.5339	0.8008	1.0677	0.1645	0.1635	0.1626	-0.8320
7	1	**1.90**	9.7	0.0575	-0.9425	0.0000	0.0000	0.1245	0.2490	0.3734	0.4979	0.5571	0.5561	0.5551	-0.5141
8	1	**1.90**	9.7	0.0574	-0.9426	0.0000	0.0000	0.1243	0.2487	0.3730	0.4974	0.5565	0.5566	0.5556	-0.5137
9	1	**1.90**	9.7	0.0573	-0.9427	0.0000	0.0000	0.1242	0.2484	0.3726	0.4968	0.5559	0.5560	0.5560	-0.5133
10	1	**2.00**	10.8	0.0000	-1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	2	**2.00**	10.8	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12	2	**2.20**	13.0	0.8320	-0.1680	0.0000	0.0000	-0.1387	-0.2773	-0.4160	-0.5547	-0.6206	-0.6207	-0.6207	-0.6933
13	2	**2.40**	15.2	0.6160	-0.3840	0.0000	0.0000	-0.1733	-0.3467	-0.5200	-0.6933	-0.7757	-0.7758	-0.7759	-0.8667
14	2	**2.60**	17.3	0.3840	-0.6160	0.0000	0.0000	-0.1387	-0.2773	-0.4160	-0.5547	-0.6206	-0.6207	-0.6207	-0.6933
15	2	**2.80**	19.5	0.1680	-0.8320	0.0000	0.0000	-0.0693	-0.1387	-0.2080	-0.2773	-0.3103	-0.3103	-0.3104	-0.3467
16	2	**3.00**	21.7	0.0000	-1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17	3	**3.00**	21.7	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18	3	**3.20**	23.8	0.8768	-0.1232	0.0000	0.0000	0.0416	0.0832	0.1248	0.1664	0.1862	0.1862	0.1862	0.2080
19	3	**3.40**	26.0	0.7024	-0.2976	0.0000	0.0000	0.0555	0.1109	0.1664	0.2219	0.2482	0.2483	0.2483	0.2773
20	3	**3.60**	28.2	0.4896	-0.5104	0.0000	0.0000	0.0485	0.0971	0.1456	0.1941	0.2172	0.2172	0.2173	0.2427
21	3	**3.80**	30.3	0.2512	-0.7488	0.0000	0.0000	0.0277	0.0555	0.0832	0.1109	0.1241	0.1241	0.1241	0.1387
22	3	**4.00**	32.5	0.0000	-1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
23	4	**4.00**	32.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

$\left(\text{matrix}(40,20,f(i,j) \leftarrow \text{""})\ \ \text{INF}_{show}\right)$

Top Slab, Influence Vectors (1 of 2)

While LRFR does apply simultaneous minimum and maximum live load factors among a given element or span (extreme effects, neglecting axles not contributing to the force under consideration, and patch lane loading), LRFR does not vary minimum and maximum permanent load factors for one load type, within the same calculation. "In the application of permanent loads, force effects for each of the specified six load types should be computed separately. It is unnecessary to assume that one type of load varies by span, length, or component within a bridge" (LRFD C3.4.1). At a two-span culvert, for example, when considering positive moment in the top slab of span 1, maximize vertical dead load throughout the entire top slab. Consistently apply maximum component (DC) and vertical earth (EV) load factors to both spans. However use the minimum horizontal earth (EH) pressure, if its effects benefit the top slab with axial force.

$iMpos := \left(INF2_{1,1}\right)^{\langle RSIF_CHK_LOCS_{1,1}\rangle}$ (1) iMpos - unfactored influence vector at $pM_{BrINC} = 1.40$ for positive moment (+M)

$iMneg := \left(INF2_{1,1}\right)^{\langle RSIF_CHK_LOCS_{2,1}\rangle}$ (2) iMneg - unfactored influence vector at 2.00 for negative moment (-M)

$iVneg := \left(INF2_{1,4}\right)^{\langle RSIF_CHK_LOCS_{3,1}\rangle}$ (3) iVneg - unfactored influence vector at $Vinc = 1.90$ for negative shear (-V)

$iMv := \left(INF2_{1,1}\right)^{\langle RSIF_CHK_LOCS_{4,1}\rangle}$ (4) iMv - unfactored influence vector at $Vinc = 1.90$ for M coincident with V (Mv)

$maxINF(INF, \gamma_{max}, \gamma_{min}) := if(INF \geq 0, \gamma_{max} \cdot INF, \gamma_{min} \cdot INF)$ $maxINF(INF, \gamma_{max}, \gamma_{min})$ - apply γ_{max} or γ_{min} to emphasize positive influence

$minINF(INF, \gamma_{max}, \gamma_{min}) := if(INF \leq 0, \gamma_{max} \cdot INF, \gamma_{min} \cdot INF)$ $minINF(INF, \gamma_{max}, \gamma_{min})$ - apply γ_{max} or γ_{min} to emphasize negative influence

$COINC(Vneg, \gamma_{max}, \gamma_{min}) := if(Vneg < 0, \gamma_{max}, \gamma_{min})$ $COINC(Vneg, \gamma_{max}, \gamma_{min})$ - use Vneg as guidance on whether to use γ_{max} or γ_{min}

$INF_LL_Mpos := \overrightarrow{maxINF(iMpos, 1, \gamma_{LLmin})}$ (1) INF_LL_Mpos - live load (LL) influence vector at $pM_{BrINC} = 1.40$ for +M

$INF_LL_Mneg := \overrightarrow{minINF(iMneg, 1, \gamma_{LLmin})}$ (2) INF_LL_Mneg - LL influence vector at 2.00 for -M

$INF_LL_Vneg := \overrightarrow{minINF(iVneg, 1, \gamma_{LLmin})}$ (3) INF_LL_Vneg - LL influence vector at $Vinc = 1.90$ for -V

$INF_LL_Mv := \overrightarrow{COINC(iVneg, iMv, 0 \cdot iMv)}$ (4) INF_LL_Mv - LL influence vector at $Vinc = 1.90$ for Mv

$INF_\gamma DC_Mpos := \gamma_{DCmax} \cdot iMpos$ (1) INF_γDC_Mpos - factored (γ) component DL (DC) infl. at $pM_{BrINC} = 1.40$ for +M

$INF_\gamma DC_Mneg := \gamma_{DCmax} \cdot iMneg$ (2) INF_γDC_Mneg - γDC influence vector at 2.00 for -M

$INF_\gamma DC_Vneg := \gamma_{DCmax} \cdot iVneg$ (3) INF_γDC_Vneg - γDC influence vector at $Vinc = 1.90$ for -V

$INF_\gamma DC_Mv := \gamma_{DCmax} \cdot iMv$ (4) INF_γDC_Mv - γDC influence vector at $Vinc = 1.90$ for Mv

$INF_\gamma EV_Mpos := \eta\gamma_{EVmax} \cdot iMpos$ (1) INF_γEV_Mpos - factored (γ) vertical earth (EV) influence at $pM_{BrINC} = 1.40$ for +M

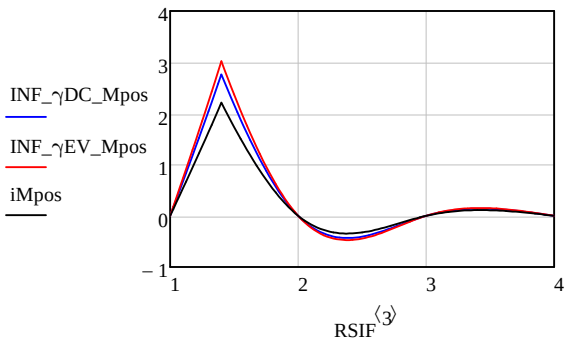
$INF_\gamma EV_Mneg := \eta\gamma_{EVmax} \cdot iMneg$ (2) INF_γEV_Mneg - γEV influence vector at 2.00 for -M

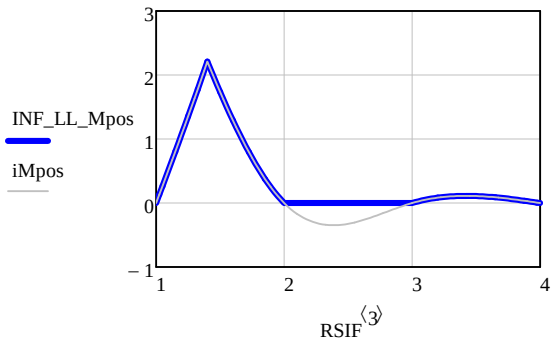
$INF_\gamma EV_Vneg := \eta\gamma_{EVmax} \cdot iVneg$ (3) INF_γEV_Vneg - γEV influence vector at $Vinc = 1.90$ for -V

$INF_\gamma EV_Mv := \eta\gamma_{EVmax} \cdot iMv$ (4) INF_γEV_Mv - γEV influence vector at $Vinc = 1.90$ for Mv

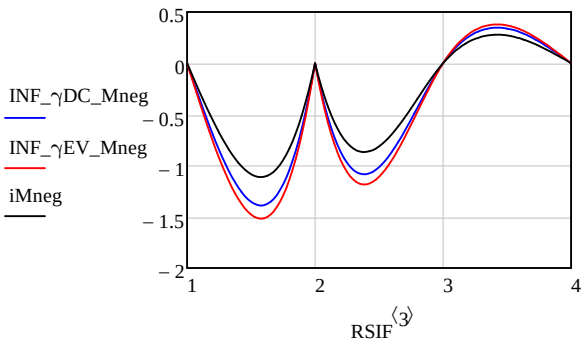
Top Slab, Influence Vectors (2 of 2)

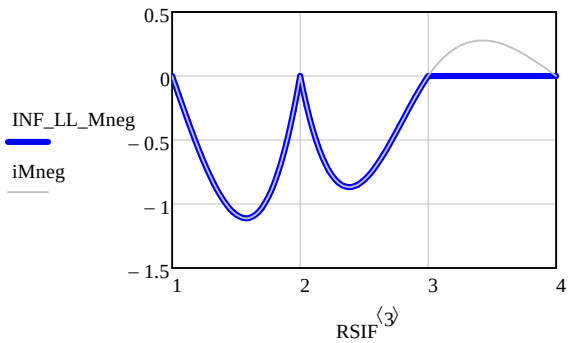
POSITIVE MOMENT



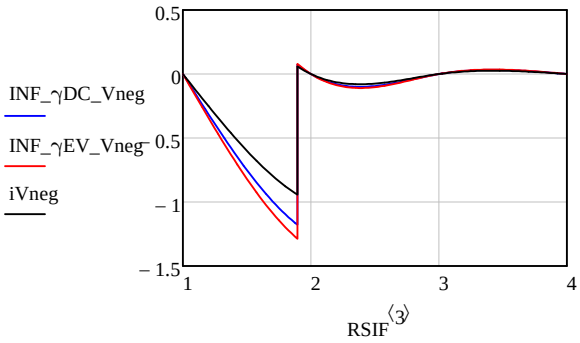


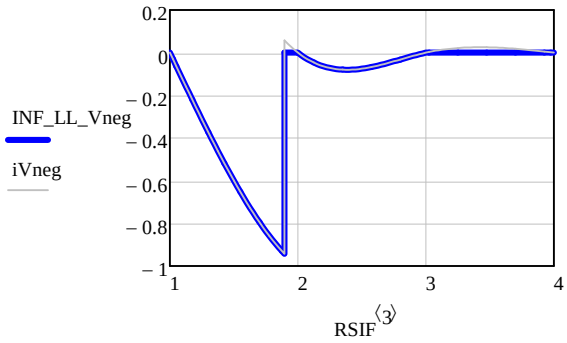
NEGATIVE MOMENT



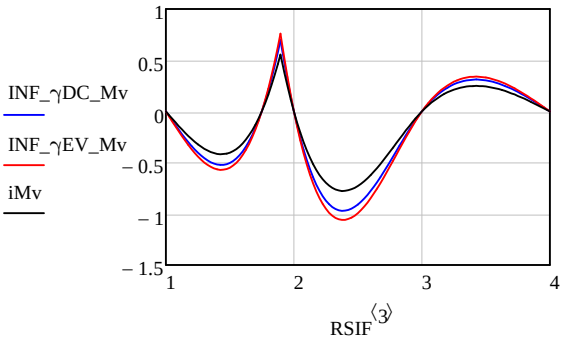


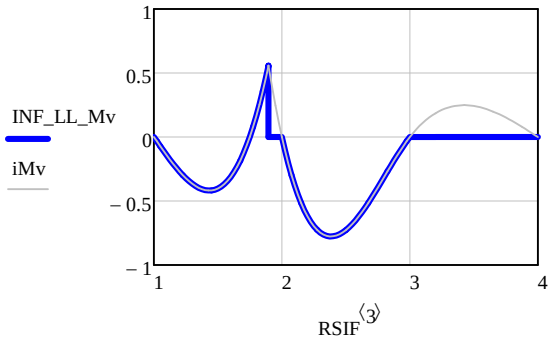
SHEAR





MOMENT ASSOCIATED WITH SHEAR





Top Slab, Apply Load to Influence (1 of 4)

UTILITIES

iftoi(FT) - given FEET, get Brinc

$$\text{iftoi}(FT) := \text{linterp}\left(RSIF^{\langle 4\rangle}, RSIF^{\langle 3\rangle}, FT\right)$$

iioft(BrINC) - given BrINC, get FEET

$$\text{iioft}(BrINC) := \text{linterp}\left(RSIF^{\langle 3\rangle}, RSIF^{\langle 4\rangle}, BrINC\right)$$

iftor(FT) - given FEET, get NODE No.

$$\text{iftor}(FT) := \text{linterp}\left(RSIF^{\langle 4\rangle}, RSIF^{\langle 1\rangle}, FT\right)$$

APPLY ω TO AN INFLUENCE VECTOR

INFx1x2a - add four nodes to an influence vector, one pair of new nodes adjacent to x1, and another new pair adjacent to x2. Add a column with bridge feet location. Output is (feet, influence).

```
INFx1x2(I, x1, x2) :=
  "if the load is not on the bridge, return 0"
  return (0  0; 0.1  0)  if x1 ≥ Σ L ∨ x2 ≤ 0
  "x1 can't be less than 0; x2 can't be greater than ΣL"
  (x1  x2) ← (max(0, x1)  min(x2, Σ L))
  "add 2 new nodes, before and after x1 &x2"
  FTadd ← stack[(x1 − 10^−6; x1 + 10^−6), (x2 − 10^−6; x2 + 10^−6)]
  "get influence for all nodes, including FTadd"
  for j ∈ 1..cols(I)
    T(x) ← linterp(RSIF^⟨4⟩, I^⟨j⟩, x)
    INFt^⟨j⟩ ← stack(I^⟨j⟩, T(FTadd))
  "combine FT & INFLUENCE, sort by FT"
  ftINF ← augment(stack(RSIF^⟨4⟩, FTadd), INFt)
  ftINF ← csort(ftINF, 1)
  "zero out any increment not within the range x1 to x2"
  ZeroLeftRight(x, INF) ← if(x < x1 ∨ x > x2, 0, INF)
  for j ∈ 2..cols(ftINF)
    ftINF^⟨j⟩ ← ZeroLeftRight(ftINF^⟨1⟩, ftINF^⟨j⟩)
  ftINF
```

INFx1x2ω(INF, x1x2ω) - for each row in x1x2ω, apply ω (klf) to influence from x1 to x2 (ft). Output is the force effect of the loading.

```
INFx1x2ω(INF, x1x2ω) :=
  T1 ← matrix(1, cols(INF), f(i, j) ← 0)
  for i ∈ 1..rows(x1x2ω)
    T2 ← INFx1x2(INF, x1x2ω_i,1, x1x2ω_i,2)
    Δ(k) ← T2_k,1 − T2_k−1,1
    I(k, j) ← (T2_k,j + T2_k−1,j) / 2
    ω ← x1x2ω_i,3
    for j ∈ 2..cols(T2)
      T3 ← Σ_{k=2}^{rows(T2)} [Δ(k)·(I(k, j)·ω)]
      T1_1,j−1 ← T1_1,j−1 + T3
  T1
```

Top Slab, Apply Load to Influence (2 of 4)

DEAD LOAD

$$DLeq(INF, \omega) := INFx1x2\omega\left[INF, \left(0 \quad \sum L \quad \frac{\omega}{klf}\right)\right]$$

$$DL(D) := \begin{pmatrix} DLeq(iMpos, \omega_{DC}) + DLeq(iMpos, \omega_{EV}(D)) \\ DLeq(iMneg, \omega_{DC}) + DLeq(iMneg, \omega_{EV}(D)) \\ DLeq(iVneg, \omega_{DC}) + DLeq(iVneg, \omega_{EV}(D)) \\ DLeq(iMv, \omega_{DC}) + DLeq(iMv, \omega_{EV}(D)) \end{pmatrix}^T$$

$$\gamma DL(D) := \begin{pmatrix} DLeq(INF_\gamma DC_Mpos, \omega_{DC}) + DLeq(INF_\gamma EV_Mpos, \omega_{EV}(D)) \\ DLeq(INF_\gamma DC_Mneg, \omega_{DC}) + DLeq(INF_\gamma EV_Mneg, \omega_{EV}(D)) \\ DLeq(INF_\gamma DC_Vneg, \omega_{DC}) + DLeq(INF_\gamma EV_Vneg, \omega_{EV}(D)) \\ DLeq(INF_\gamma DC_Mv, \omega_{DC}) + DLeq(INF_\gamma EV_Mv, \omega_{EV}(D)) \end{pmatrix}^T$$

$$DL := \left| \begin{array}{l} \text{for } iD \in 1..rows(D_{fills}) \\ \quad T^{\langle iD \rangle} \leftarrow DL(D_{fills_{iD}})^T \\ T^T \end{array} \right.$$

$$\gamma DL := \left| \begin{array}{l} \text{for } iD \in 1..rows(D_{fills}) \\ \quad T^{\langle iD \rangle} \leftarrow \gamma DL(D_{fills_{iD}})^T \\ T^T \end{array} \right.$$

$$DL = \begin{bmatrix} (3.37) & (-4.21) & (-1.92) & (-1.79) \\ (4.18) & (-5.22) & (-2.39) & (-2.22) \end{bmatrix}$$

$$\gamma DL = \begin{bmatrix} (4.46) & (-5.57) & (-2.55) & (-2.37) \\ (5.57) & (-6.95) & (-3.18) & (-2.96) \end{bmatrix}$$

DISTRIBUTED TRUCK

OLAPTRK2(TRK, D) - given a truck (ft kip), make a longitudinally distributed truck (x_start x_end klf). Where axle distribution lengths overlap, the tributary axles are uniformly distributed over the net length (Std.Spec. 6.4.2 & LRFD MBE C6A.5.12.10.3a). When axle overlapping does occur, heavy axle areas may be irrationally distributed to light axle areas. However, such overlapping occurs under deep fills, where DL supercedes LL.

$$OLAPTRK2(TRK, D) := \left| \begin{array}{l} E_{long} \leftarrow E_{long.eq}(D) \cdot ft^{-1} \\ \text{return} \left(-0.5 \cdot E_{long} \quad 0.5 \cdot E_{long} \quad \frac{TRK_{1,2}}{E_{long}}\right) \text{ if } rows(TRK) = 1 \\ (T \quad CL_AXLE) \leftarrow \left[\left(-0.5 \cdot E_{long} \quad 0.5 \cdot E_{long} \quad TRK_{1,2}\right) \quad (0)\right] \\ \text{for } i \in 2..rows(TRK) \\ \quad \left| \begin{array}{l} (r \quad CL_AXLE) \leftarrow \left[rows(T) \quad \left(CL_AXLE - TRK_{i,1}\right)\right] \\ T \leftarrow \left| \begin{array}{l} stack\left[T, \left[\left(CL_AXLE - 0.5 \cdot E_{long}\right) \quad \left(CL_AXLE + 0.5 \cdot E_{long}\right) \quad TRK_{i,2}\right]\right] \text{ if } TRK_{i,1} > E_{long} \\ \left(T_{r,1} \quad T_{r,2} \quad T_{r,3}\right) \leftarrow \left[\left(CL_AXLE - 0.5 \cdot E_{long}\right) \quad \left(T_{r,2}\right) \quad \left(T_{r,3} + TRK_{i,2}\right)\right] \text{ otherwise} \end{array} \right. \end{array} \right. \\ \text{for } i \in 1..rows(T) \\ \quad T_{i,3} \leftarrow \frac{T_{i,3}}{T_{i,2} - T_{i,1}} \\ T \end{array} \right.$$

MAKE DISTRIBUTED TRUCKS

TKLOCS2 - (x_start, x_end, unfactored pressure) and (locations of first wheel in bridge feet), no lateral distribution, no IM, and no load factor)

$$
\begin{aligned}
\text{TKLOCS2}(TK, D) := \;& T \leftarrow \text{OLAPTRK2}(TK, D) \\
& TRK_LEN \leftarrow \max\left(T^{\langle 2 \rangle}\right) - \min\left(T^{\langle 1 \rangle}\right) \\
& RUN_LEN \leftarrow TRK_LEN + 1.2 \cdot L_1 \\
& \text{for } i \in 1..ips_{LL} + 1 \\
& \quad x_i \leftarrow \frac{RUN_LEN}{ips_{LL}} \cdot (i - 1) + 0.4 \cdot L_1 \\
& \text{for } i \in 1..\text{rows}(x) \\
& \quad T2_i \leftarrow \text{augment}\left(T^{\langle 1 \rangle} + x_i, T^{\langle 2 \rangle} + x_i, T^{\langle 3 \rangle}\right) \\
& T2
\end{aligned}
$$

MIRROR(TRK) - reverse the truck for two-way traffic

$$
\begin{aligned}
\text{MIRROR}(TRK) := \;& \text{for } i \in 1..\text{rows}(TRK) \\
& \quad T2_{i,1} \leftarrow \begin{cases} 0 & \text{if } i = 1 \\ TRK_{\text{rows}(TRK)-i+2,1} & \text{otherwise} \end{cases} \\
& \quad T2_{i,2} \leftarrow TRK_{\text{rows}(TRK)-i+1,2} \\
& \text{return } T2 \text{ if } \text{cols}(TRK) = 2 \\
& \text{augment}\left(T2, TRK^{\langle 3 \rangle}\right)
\end{aligned}
$$

RUN LIVE LOAD

$\gamma LLwLBL(D)$ - factored live load with distribution and impact for one fill depth. 1 vehicle per row.

Main columns are:
(1) LL details
(2) M.positive
(3) M.negative
(4) V.negative
(5) M.coincident.with.Vnegative

Submatrix (1) LL detail columns:
(1) Row No.
(2) Veh No.
(3) Veh Name
(4) Truck No.
(5) Forward/Reverse 0/1
(6) 0
(7) Factored Truck

Submatrix (7) Factored Truck Columns are:
(1) x.start - the place in bridge feet at which the loading begins
(2) x.end - the place in bridge feet at which the loading ends
(3) klf loading - γ.LL*DF*IM*(AXLE, or ΣAXLES for overlapped axles)

```
γLLwLBL(D) := | VEHS ← TRUCKS
              | IM ← IMeq(D)
              | for iv ∈ 1..rows(VEHS)
              |   | VEH ← VEHS[iv,1]
              |   | DF ← LLDFeq(mpf[iv], D)
              |   | (Mp Mn Vn M_Vn row) ← (0 0 0 0 0)
              |   | for iTRK ∈ 1..rows(VEHS[iv,2])
              |   |   | TRK1 ← (TRUCKS[iv,2])[iTRK,1]
              |   |   | for iMIRR ∈ 1..2
              |   |   |   | TRK2 ← | TRK1 if iMIRR = 1
              |   |   |   |        | MIRROR(TRK1) otherwise
              |   |   |   | TKS ← TKLOCS2(TRK2, D)
              |   |   |   | for itrk ∈ 1..rows(TKS)
              |   |   |   |   | r ← r + 1
              |   |   |   |   | x_lead ← (TKS[itrk])[rows(TKS[itrk]),3]
              |   |   |   |   | (TKS[itrk])⟨3⟩ ← γLL[iv]·DF·IM·(TKS[itrk])⟨3⟩
              |   |   |   |   | TK ← TKS[itrk]
              |   |   |   |   | T⟨r⟩ ← (r iv VEH iTRK iMIRR − 1 0 TKS[itrk])^T
              |   |   |   |   | (Mp⟨r⟩ Mn⟨r⟩ Vn⟨r⟩ M_Vn⟨r⟩) ← (INFx1x2ω(INF_LL_Mpos, TK)^T
              |   |   |   |   |                  INFx1x2ω(INF_LL_Mneg, TK)^T
              |   |   |   |   |                  INFx1x2ω(INF_LL_Vneg, TK)^T
              |   |   |   |   |                  INFx1x2ω(INF_LL_Mv, TK)^T)
              |   | γLL⟨iv⟩ ← (T^T Mp^T Mn^T Vn^T M_Vn^T)^T
              |   | (T Mp Mn Vn McφoincVn) ← (0 0 0 0 0)
              |   | r ← 0
              | γLL^T
```

Top Slab, Capacity

MOMENT, LFR OR LRFR

$Mn := f_y \cdot A_s \cdot \left(d - \frac{1}{2} \cdot \frac{f_y \cdot A_s}{0.85 \cdot f_c \cdot ft}\right)$ $Mn = 22.73 \cdot kip \cdot ft$ - nominal flexural capacity (Std.Spec. Eq.8-16, LRFD Eq. 5.7.3.2.2-1)

$\phi_M := 0.90$ $\phi_M = 0.90$ - flexural strength reduction (Std.Spec. 8.16.1.2.2, LRFD Table 12.5.5-1)

$\psi\phi Mn := \psi_c \cdot \phi_M \cdot Mn$ $\psi\phi Mn = 20.46 \cdot kip \cdot ft$ - factored flexural strength; condition factor is $\psi_c = 1.00$

SHEAR, LFR OR LRFR D.FILL > 2 FEET

$$Vn_{DeepFills}(Mu, Vu) := \left| \begin{array}{l} \sigma \leftarrow if\left(cells = 1, 2.5 \cdot \sqrt{f_c \cdot psi}, 0\right) \\ \sigma \leftarrow max\left(\sigma, 2.14 \cdot \sqrt{f_c \cdot psi} + 4600 \cdot psi\, \rho \cdot min\left(1, \frac{|Vu| \cdot d}{|Mu|}\right)\right) \\ min\left(\sigma, 4.0 \cdot \sqrt{f_c \cdot psi}\right) \cdot ft \cdot d \end{array} \right.$$

- nominal shear strength, D.fill > 2 feet (Std.Spec. 8.16.6.7.1, LRFD 5.14.5.3)

SHEAR, LFR D.FILL < 2 FEET

$$Vn_{LFR_Shallow}(Mu, Vu) := \left| \begin{array}{l} \sigma \leftarrow 1.9 \cdot \sqrt{f_c \cdot psi} + 2500 \cdot psi\, \rho \cdot min\left(1, \frac{|Vu| \cdot d}{|Mu|}\right) \\ min\left(\sigma, 3.5 \cdot \sqrt{f_c \cdot psi}\right) \cdot ft \cdot d \end{array} \right.$$

- nominal shear strength for LFR when D.fill < 2 feet (Std.Spec. Eq. 8-48)

SHEAR, LRFR D.FILL < 2 FEET

For LRFR D.fill < 2 feet, use LRFD 5.8.3.3. For box culverts that neglect axial loading, LRFD Equations 5.8.3.4.2-2 and Eq. 5.8.3.4.2-4 reduce to:

$d_v := \frac{Mn}{A_s \cdot f_y}$ $d_v = 8.07 \cdot in$ - distance between tension and compression centroids at full strength

$$\varepsilon_{s.min}(Mu, Vu) := \frac{\frac{max\left(|Mu|, |Vu| \cdot d_v\right)}{d_v} + |Vu|}{29000ksi \cdot A_s}$$

$\varepsilon_{s.min}(Mu, Vu)$- strain at the centroid of reinforcement

$s_{xe} := min\left(max\left(12in, d_v \cdot \frac{1.38}{0.375 + 0.63}\right), 80in\right)$ $s_{xe} = 12.00 \cdot in$ - crack spacing parameter, assuming max aggregate size = 3/8in.

$$\beta(Mu, Vu) := \frac{4.8}{1 + 750 \cdot min\left(\varepsilon_{s.min}(Mu, Vu), 6 \cdot 10^{-3}\right)} \cdot \frac{51in}{39in + s_{xe}}$$

$\beta(Mu, Vu)$- shear capacity factor

$Vn_{LRFR_Shallow}(Mu, Vu) := \beta(Mu, Vu) \cdot \sqrt{f_c \cdot psi} \cdot ft \cdot d_v$ $Vn_{LRFR_Shallow}(Mu, Vu)$ - concrete shear capacity

FACTORED SHEAR CAPACITY

$\phi_V := 0.85$ - strength reduction factor for shear (Std.Spec. 8.16.1.2.2, LRFD Table 12.5.5-1, neglecting LRFD 5.5.4.2.1 ϕ.V = 0.90 for slabs & shallow fills)

$$\psi\phi Vn(Mu, Vu, D) := \left| \begin{array}{l} return\ \psi_c \cdot \phi_V \cdot Vn_{DeepFills}(Mu, Vu)\ \ if\ \ D \geq 2ft \\ return\ \psi_c \cdot \phi_V \cdot Vn_{LFR_Shallow}(Mu, Vu)\ \ if\ \ LRFR = 0 \\ return\ \psi_c \cdot \phi_V \cdot Vn_{LRFR_Shallow}(Mu, Vu)\ \ if\ \ LRFR = 1 \\ "ERROR" \end{array} \right.$$

- factored shear strength; condition factor is $\psi_c = 1.00$

Exterior Wall (1 of 6)

$D_{fill} := \max(D_{fills})$ — $D_{fill} = 2.60\,ft$ - covering fill

$\gamma_{LL.Inventory} := \gamma_{LL_1}$ — $\gamma_{LL.Inventory} = 1.75$ - live load factor, Inventory Level

$\omega_{DC} = 0.128 \cdot klf \quad \gamma_{soil} = 120 \cdot pcf$ — ω_{DC} & γ_{soil} - previously defined terms

$\omega_{EV.Wall} := \omega_{EV}(D_{fill})$ — $\omega_{EV.Wall} = 0.317 \cdot klf$ - vertical earth (EV) loading for exterior wall

VERTICAL LOADS

Axial loads, designated by "P," are positive for tension, and negative for compression.

$INF\omega := (0.5000 \quad 0.3750 \quad 0.4000 \quad 0.3928)_{1,\min(cells,4)} \cdot L_1 \cdot \frac{kip}{klf}$ — $INF\omega = 4.33 \cdot \frac{kip}{klf}$ - influence, klf (ω) top slab to ext. wall rxn: +Area, -Area, ΣArea

$INFp := (0 \quad -0.096 \quad -0.08 \quad -0.0789)_{1,\min(cells,4)}$ — $INFp = -0.08 \cdot \frac{kip}{kip}$ - uplifting influence, kip onto exterior wall per 1 kip axle in span 2

$DC_P := -\omega_{DC} \cdot INF\omega$ — $DC_P = -0.56 \cdot kip$ - slab component load (DC), axial compression (P) onto exterior wall

$\gamma DC_P := -\gamma_{DCmin} \cdot \omega_{DC} \cdot INF\omega$ — $\gamma DC_P = -0.50 \cdot kip$ - minimized factored DC_P

$EV_P := -\omega_{EV.Wall} \cdot INF\omega$ — $EV_P = -1.37 \cdot kip$ - vertical earth (EV) axial comp. (P) onto ext wall. $F_{e.eq}(D_{fill}) = 1.02$

$\gamma EV_P := -\eta\gamma_{EVmin} \cdot \omega_{EV.Wall} \cdot INF\omega$ — $\gamma EV_P = -1.24 \cdot kip$ - minimized factored EV_P

$LV_P := -IMeq(D_{fill}) \cdot LLDFeq(mpf_1, D_{fill}) \cdot (32kip \cdot INFp)$ — $LV_P = 0.36 \cdot kip$ - vertical live load (LV) axial tension (P), 32 kip axle load, where:
$IMeq(D_{fill}) = 1.223 \quad mpf_1 = 1.20 \quad LLDFeq(mpf_1, D_{fill}) = 0.1141$

$\gamma LV_P := \gamma_{LL.Inventory} \cdot LV_P$ — $\gamma LV_P = 0.63 \cdot kip$ - minimized factored LV_P.

$F_s := A_{s.wall} \cdot f_y = 19.84 \cdot kip$ — F_s - force of steel at yield

$$a := \frac{F_s + (\gamma DC_P + \gamma EV_P + \gamma LV_P)}{0.85 \cdot f_c \cdot 12in}$$ — $a = 0.61 \cdot in$ - effective depth of the compression block

$$d_{ax.to.c} := \frac{d_{wall}}{2} - \frac{a}{2}$$ — $d_{ax.to.c} = 3.91 \cdot in$ - axial load to CG compression

$DC_M := DC_P \cdot d_{ax.to.c} \qquad \gamma DC_M := \gamma DC_P \cdot d_{ax.to.c}$ — $DC_M = -0.18 \cdot kip \cdot ft$ & $\gamma DC_M = -0.16 \cdot kip \cdot ft$
Unfactored and factored moment from slab component load (DC)

$EV_M := EV_P \cdot d_{ax.to.c} \qquad \gamma EV_M := \gamma EV_P \cdot d_{ax.to.c}$ — $EV_M = -0.45 \cdot kip \cdot ft$ &
Unfactored and factored moment from vertical earth (EV)

$LV_M := LV_P \cdot d_{ax.to.c} \qquad \gamma LV_M := \gamma LV_P \cdot d_{ax.to.c}$ — $LV_M = 0.12 \cdot kip \cdot ft$ & $\gamma LV_M = 0.20 \cdot kip \cdot ft$
Unfactored and factored moment from vertical live load (LV)

$\psi c\phi Mn_wall := \psi_c \cdot \phi_M \cdot F_s \cdot \left(d_{wall} - \frac{a}{2}\right)$ — $\psi c\phi Mn_wall = 12.10 \cdot kip \cdot ft$ - factored flexural capacity, exterior wall

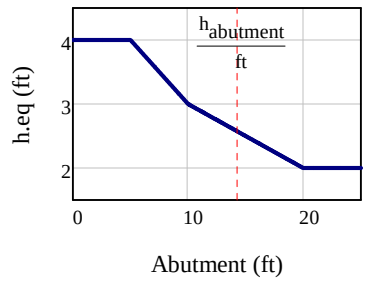
EQUIVALENT HEIGHT

$h_{abutment} := D_{fill} + 2 \cdot t_{slab} + h_{clear}$

$h_{abutment} = 14.31\,ft$ - overall height of the abutment

$$h_{eq.equation}(h_{abutment}) := \left| \begin{array}{l} h \leftarrow h_{abutment} \\ \text{return } 2ft \text{ if } LRFR = 0 \\ \text{return } 4ft \text{ if } h < 5ft \\ \text{return } 2ft \text{ if } h > 20ft \\ \text{linterp}\left[\begin{pmatrix} 5 \\ 10 \\ 20 \end{pmatrix} ft, \begin{pmatrix} 4 \\ 3 \\ 2 \end{pmatrix} ft, h\right] \end{array} \right.$$

$h_{eq.equation}$ - equivalent surcharge for LL (Std.Spec. 3.20.3, LRFD 3.11.6.4-1)



$h_{eq} := h_{eq.equation}(h_{abutment})$

$h_{eq} = 2.57\,ft$ - equivalent surcharge height for live load

SIMPLE SPAN EQUATIONS

$$\omega_{\omega1.\omega2.eq}(\omega_{start}, \omega_{end}, L, x) := \text{if}\left[0 \le x \le L, \omega_{start} + (\omega_{end} - \omega_{start}) \cdot \left(\frac{x}{L}\right), 0\right]$$

$ix := 1 .. 41$

$$V_{\omega1.\omega2.eq}(\omega_{start}, \omega_{end}, L, x) := \text{if}\left[0 \le x \le L, \left[\omega_{start} \cdot \left(\frac{L}{2} - x\right) + (\omega_{end} - \omega_{start}) \cdot \left(\frac{L}{6} - \frac{x^2}{2 \cdot L}\right)\right], 0\right]$$

$$FT_{ix} := \frac{ix - 1}{40} \cdot L_{wall}$$

$$M_{\omega1.\omega2.eq}(\omega_{start}, \omega_{end}, L, x) := \text{if}\left[0 \le x \le L, \left[\omega_{start} \cdot \left(\frac{L}{2} \cdot x - \frac{x^2}{2}\right)\right] + (\omega_{end} - \omega_{start}) \cdot \left(\frac{L \cdot x}{6} - \frac{x^3}{6 \cdot L}\right), 0\right]$$

$$FT := \text{stack}\left[\left(-10^{-3} \cdot ft\right), FT, \left(\max(FT) + 10^{-3} \cdot ft\right)\right]$$

$x_{origin} := h_{abutment} - t_{slab} - h_{haunch.bot}$

$x_{origin} = 13.12\,ft$ - the depth of "x origin," at the bottom construction joint

HORIZONTAL EARTH (EH)

$\omega_{EH.start} := \omega_{EH}(x_{origin}) = 0.787 \cdot klf$

$\omega_{EH.end} := \omega_{EH}(x_{origin} - L_{wall}) = 0.217 \cdot klf$

$EH_{\omega} := \overrightarrow{\omega_{\omega1.\omega2.eq}(\omega_{EH.start}, \omega_{EH.end}, L_{wall}, FT)}$

$EH_{V} := \overrightarrow{V_{\omega1.\omega2.eq}(\omega_{EH.start}, \omega_{EH.end}, L_{wall}, FT)}$

$EH_{M} := \overrightarrow{M_{\omega1.\omega2.eq}(\omega_{EH.start}, \omega_{EH.end}, L_{wall}, FT)}$

$\gamma EH_M := \eta\gamma_{EHmax} \cdot EH_M \quad \max(\gamma EH_M) = 8.10 \cdot kip \cdot ft$

HORIZONTAL LL FROM SURCHARGE (LS)

$\omega_{LS.start} := \omega_{EH}(h_{eq}) = 0.154 \cdot klf$

$\omega_{LS.end} := \omega_{EH}(h_{eq}) = 0.154 \cdot klf$

$LS_{\omega} := \overrightarrow{\omega_{\omega1.\omega2.eq}(\omega_{LS.start}, \omega_{LS.end}, L_{wall}, FT)}$

$LS_{V} := \overrightarrow{V_{\omega1.\omega2.eq}(\omega_{LS.start}, \omega_{LS.end}, L_{wall}, FT)}$

$LS_{M} := \overrightarrow{M_{\omega1.\omega2.eq}(\omega_{LS.start}, \omega_{LS.end}, L_{wall}, FT)}$

$\gamma LS_M := \gamma_{LL.Inventory} \cdot LS_M \quad \max(\gamma LS_M) = 3.04 \cdot kip \cdot ft$

APPROXIMATE RATING FACTOR, DESIGN INVENTORY

$\psi c\phi Mn_wall = 12.10 \cdot kip \cdot ft$

$DC_M = -0.18 \cdot kip \cdot ft$ $\quad \gamma DC_M = -0.16 \cdot kip \cdot ft$ $\quad DC_M$ - component dead load, reduces the wall moment (-)

$EV_M = -0.45 \cdot kip \cdot ft$ $\quad \gamma EV_M = -0.40 \cdot kip \cdot ft$ $\quad EV_M$ - vertical earth, reduces the wall moment (-)

$\max(EH_M) = 5.72 \cdot kip \cdot ft$ $\quad \max(\gamma EH_M) = 8.10 \cdot kip \cdot ft$ $\quad EH_M$ - horizontal earth, increases the wall moment (+)

$LV_M = 0.12 \cdot kip \cdot ft$ $\quad \gamma LV_M = 0.20 \cdot kip \cdot ft$ $\quad LV_M$ - vertical live load uplift, from axle in span 2, increases the wall moment (+)

$\max(LS_M) = 1.74 \cdot kip \cdot ft$ $\quad \max(\gamma LS_M) = 3.04 \cdot kip \cdot ft$ $\quad LS_M$ - horizontal LL from a vertical surcharge increases wall moment (+)

$$RF_{approx} := \frac{\psi c\phi Mn_wall - (\gamma DC_M + \gamma EV_M + \max(\gamma EH_M))}{\gamma LV_M + \max(\gamma LS_M)} = 1.405$$

RF_{approx} - approximate the Design Vehicle RF at the Inventory Level

RATING FACTOR, DESIGN INVENTORY

$DL_{wall} := DC_M + EV_M + EH_M$ $\quad \gamma DL_{wall} := \gamma DC_M + \gamma EV_M + \gamma EH_M$ $\quad DL_{wall}$ & γDL_{wall} - unfactored and factored DL

$LL_{wall} := LV_M + LS_M$ $\quad \gamma LL_{wall} := \gamma LV_M + \gamma LS_M$ $\quad LL_{wall}$ & γLL_{wall} - unfactored and factored LL

$$RFs := \left| \begin{array}{l} mx(A,B) \leftarrow \max(A,B) \\ \overrightarrow{\dfrac{\psi c\phi Mn_wall - \gamma DL_{wall}}{mx\left(10^{-6} kip \cdot ft, \gamma LL_{wall}\right)}} \end{array} \right.$$

$RF_{Des.Inv} := \min(RFs)$

$$ROW_ExtWall := \left| \begin{array}{l} T \leftarrow RF_{Des.Inv} \\ match2(T, RFs) \end{array} \right.$$

$RF_{Des.Inv} = 1.413$ - exterior wall rating factor, Design Inventory

$ROW_ExtWall = 21.00$ - governing row No.

$$\frac{LL_{wall_{ROW_ExtWall}}}{DL_{wall_{ROW_ExtWall}}} = 0.36$$

VERIFY ϕ.M = 0.90

$\beta_{1.eq}(f_c) := \text{if}\left(f_c \le 4ksi, 0.85, \max\left(0.65, 0.85 - 0.20\cdot\frac{f_c - 4ksi}{4ksi}\right)\right)$

$\beta_1 := \beta_{1.eq}(f_c) = 0.85$ - a/c (LRFD 5.7.2.2)

$c := \frac{a}{\beta_1} = 0.72\cdot in$

c - distance to the neutral axis, under factored loading

$\varepsilon_t := 0.003\cdot\frac{d - c}{c} = 0.033$

ε_t - steel tension when $\varepsilon_{conc} = 0.003$

$CHECK := \text{if}\left(\varepsilon_t \ge \frac{f_y}{29000ksi}, \text{"OK: ε.steel > ε.yield"}, \text{"ERROR: ε.steel < ε.yield; revise calculations "}\right)$ ... CHECK = "OK: ε.steel > ε.yield"

$RF_{Des.Inv} := \text{if}(CHECK = \text{"OK: ε.steel > ε.yield"}, RF_{Des.Inv}, 0) = 1.41$

$RF_{Des.Inv} = 1.41$ - if ε.steel < ε.yield, revise the rating factor to 0

$\phi eq(\varepsilon_t, \varepsilon_{cl}, \varepsilon_{tl}) := \text{if}\left(\varepsilon_t \le \varepsilon_{cl}, 0.75, \min\left(0.90, 0.75 + 0.15\cdot\frac{\varepsilon_t - \varepsilon_{cl}}{\varepsilon_{tl} - \varepsilon_{cl}}\right)\right)$

$\phi eq(\varepsilon_t, \varepsilon_{cl}, \varepsilon_{tl})$ - flexural resistance factor equation (LRFD 5.5.4.2.1)

$\varepsilon_{cl} := \frac{f_y}{29000ksi} = 0.0014$

ε_{cl} - compression controlled limit; when $\varepsilon_{conc} = 0.003$ and $\varepsilon_t = \varepsilon_{yield}$

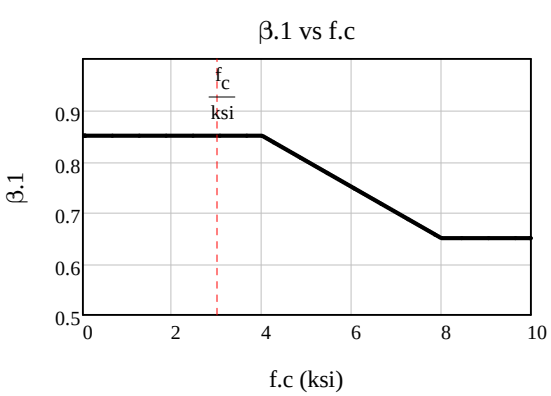
$\varepsilon_{tl} := 0.005$

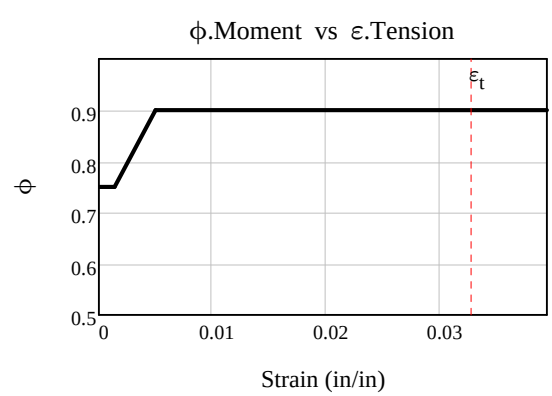
ε_{tl} - tension controlled limit; when $\varepsilon_{conc} = 0.003$ and $\varepsilon_t = 0.005$

$\phi := \phi eq(\varepsilon_t, \varepsilon_{cl}, \varepsilon_{tl}) = 0.90$

$\phi = 0.90$ - flexural resistance/reduction factor (also see Std.Spec. 8.16.1.2.2)

Also see Std.Spec. 8.16.1.2.2, and ACI 10.3.5. For factored axial loading less than n $0.1\cdot f_c\cdot t_{ExtWall}\cdot ft = 36.00\cdot kip$, if ε.t > 0.004, then $\phi = 0.90$.





Exterior Wall (5 of 6)

DRAW EXTERIOR WALL

$$KEY := \begin{pmatrix} 0 & 0 \\ 0.333\cdot t_{ExtWall} - 0.125in & 0 \\ 0.375in & -1.625in \\ 0.333\cdot t_{ExtWall} - 0.375in & 0 \\ 0.375in & 1.625in \\ 0.333\cdot t_{ExtWall} - 0.125in & 0 \end{pmatrix}$$

$$DRAWxy(xy) := \left| \begin{array}{l} T \leftarrow \left(xy^T\right)^{\langle 1 \rangle} \\ \text{for } i \in 2..rows(xy) \\ \quad T^{\langle i \rangle} \leftarrow T^{\langle i-1 \rangle} + \left(xy^T\right)^{\langle i \rangle} \\ T^T \end{array} \right.$$

$$MIRRORX(MATRX) := \left| \begin{array}{l} T \leftarrow MATRX \\ \text{for } i \in 1..rows(T) \\ \quad T_{i,1} \leftarrow -T_{i,1} \\ T \end{array} \right.$$

$$CBC := \left| \begin{array}{l} T \leftarrow stack\left[\begin{bmatrix} 0 & 0 \\ \left(t_{ExtWall} + 0.5\cdot W_c\right) & 0 \\ -\left(t_{ExtWall} + 0.5\cdot W_c\right) & 0 \\ 0 & \left(t_{slab} + 4in\right) \end{bmatrix}, KEY, \begin{pmatrix} 0 & -4in \\ 0.5\cdot W_c & 0 \\ -0.5\cdot W_c & 0 \end{pmatrix}\right] \\ DRAWxy\left[stack\left[T, \begin{bmatrix} 0 & \left(h_{clear} - 2in\right) \\ 2in & 2in \\ \left(0.5\cdot W_c - 2in\right) & 0 \\ -\left(0.5\cdot W_c - 2in\right) & 0 \\ -2in & -2in \end{bmatrix}, MIRRORX(KEY), \begin{bmatrix} 0 & \left(2in + t_{slab}\right) \\ \left(0.5\cdot W_c + t_{ExtWall}\right) & 0 \\ -\left(0.5\cdot W_c + t_{ExtWall}\right) & 0 \\ 0 & -\left(h_{clear} + t_{slab}\right) \end{bmatrix}\right]\right] \end{array} \right.$$

$$CBC^{\langle 2 \rangle} := CBC^{\langle 2 \rangle} - \left(h_{abutment} - x_{origin}\right)$$

DRAW ROADWAY SURFACE

$$ROAD := \left| \begin{array}{l} T \leftarrow (-2 \quad 0) \\ \text{for } i \in 1..200 \\ \quad \left| \begin{array}{l} (Tx \quad Ty) \leftarrow \left(T_{rows(T),1} \quad T_{rows(T),2}\right) \\ T \leftarrow stack\left[T, \begin{pmatrix} Tx + 0.5 & Ty \\ Tx + 0.25 & Ty - 0.5 \\ Tx + 0.5 & Ty \end{pmatrix}\right] \end{array} \right. \\ T^{\langle 2 \rangle} \leftarrow T^{\langle 2 \rangle} + \frac{x_{origin}}{ft} \\ T^{\langle 1 \rangle} \leftarrow T^{\langle 1 \rangle} - 40 \\ T \end{array} \right.$$

DRAW CULVERT TOP SLAB

$$CBC2 := \left| \begin{array}{l} T \leftarrow stack[(0), SUML(L)]\cdot ft \\ T2 \leftarrow (0 \quad 0) \\ LEG(t,x) \leftarrow \begin{pmatrix} x - 0.5\cdot t & 0 \\ x - 0.5\cdot t & -2ft \\ x - 0.5\cdot t & 0 \\ x + 0.5\cdot t & 0 \\ x + 0.5\cdot t & -2ft \\ x + 0.5\cdot t & 0 \end{pmatrix} \\ \text{for } i \in 1..rows(T) \\ \quad T2 \leftarrow stack\left(T2, LEG\left(\left| \begin{array}{ll} t_{ExtWall} & \text{if } i = 1 \vee i = rows(T) \\ t_{IntWall} & \text{otherwise} \end{array} \right., T_i\right)\right) \\ T2 \leftarrow stack\left[T2, \begin{pmatrix} \max\left(T2^{\langle 1 \rangle}\right) & t_{slab} \\ -0.5\cdot t_{ExtWall} & t_{slab} \\ -0.5\cdot t_{ExtWall} & 0 \end{pmatrix}\right] \\ T2^{\langle 2 \rangle} \leftarrow T2^{\langle 2 \rangle} - \max\left(T2^{\langle 2 \rangle}\right) \\ T2 \end{array} \right.$$

PLOT RANGES

$$plt_\omega min := 1.2\cdot min\left(-EH_\omega, -LS_\omega\right) = -0.94\cdot klf$$

$$plt_Vmin := 1.2\cdot min\left(-EH_V, -LS_V\right) = -3.40\cdot kip$$

$$plt_Vmax := 1.2\cdot max\left(-EH_V, -LS_V\right) = 2.32\cdot kip$$

$$plt_Mmin := 1.2\cdot min\left(-EH_M, -LS_M\right) = -6.86\cdot kip\cdot ft$$

$$FT_ExtWall := FT$$

RATING FACTOR DETAILS

n2s(N, DP) - number to string; show trailing zeroes

```
n2s(N, DP) := | N2str ← num2str(round(N, DP))
              | N2str ← concat(N2str, ".")  if  search(N2str, ".", 0) = −1
              | while  strlen(N2str) − search(N2str, ".", 0) < DP + 1
              |   N2str ← concat(N2str, "0")
              | N2str
```

GVW - gross vehicle weights in tons

$$\mathrm{GVW} := \left| \begin{array}{l} \mathrm{GVWeq1}(\mathrm{TRK}) \leftarrow 0.5 \cdot \sum \mathrm{TRK}^{\langle 2 \rangle} \\ \mathrm{GVWeq2}(\mathrm{TRKS}) \leftarrow \max\left(\overrightarrow{\mathrm{GVWeq1}(\mathrm{TRKS})}\right) \\ \mathrm{augment}\left(\mathrm{TRUCKS}^{\langle 1 \rangle}, \overrightarrow{\mathrm{GVWeq2}\left(\mathrm{TRUCKS}^{\langle 2 \rangle}\right)}\right) \end{array} \right.$$

RF_ExtWall(iv) -exterior wall rating factor details for each vehicle No.' iv"

$$\mathrm{RF_ExtWall}(iv) := \left| \begin{array}{l} r \leftarrow \mathrm{ROW_ExtWall} \\ \mathrm{RF} \leftarrow \dfrac{\gamma\mathrm{LL_eq}(1)}{\gamma\mathrm{LL_eq}(iv)} \cdot \dfrac{\mathrm{mpf_eq}(1)}{\mathrm{mpf_eq}(iv)} \cdot \dfrac{\mathrm{GVW}_{1,2}}{\mathrm{GVW}_{iv,2}} \cdot \mathrm{RF}_{\mathrm{Des.Inv}} \\ \mathrm{MSSG}_{\mathrm{RF}} \leftarrow \left| \begin{array}{l} T \leftarrow \mathrm{concat}(\text{"RF = ["}, \mathrm{n2s}(\gamma\mathrm{LL_eq}(1), 2), \text{"/"}, \mathrm{n2s}(\gamma\mathrm{LL_eq}(iv), 2), \text{"]["}, \mathrm{n2s}(\mathrm{mpf_eq}(1), 2), \text{"/"}, \mathrm{n2s}(\mathrm{mpf_eq}(iv), 2), \text{"]["}) \\ T \leftarrow \mathrm{concat}\left[T, \mathrm{num2str}\left(\mathrm{GVW}_{1,2}\right), (\text{"/"}), \mathrm{num2str}\left(\mathrm{GVW}_{iv,2}\right), \text{"][("}\right] \\ \mathrm{concat}\left[T, \mathrm{n2s}\left(\dfrac{\psi c\phi Mn_wall}{kip \cdot ft}, 2\right), \text{" - "}, \mathrm{n2s}\left(\dfrac{\gamma DC_M + \gamma EV_M + \gamma EH_{M_r}}{kip \cdot ft}, 2\right), \text{") / ("}, \mathrm{n2s}\left(\dfrac{\gamma LV_M + \gamma LS_{M_r}}{kip \cdot ft}, 2\right), \text{")] = "}, (\mathrm{n2s}(\mathrm{RF}, 2))\right] \end{array} \right. \\ \mathrm{MSSG}_{\mathrm{LOC}} \leftarrow \mathrm{concat}\left(\text{"Ext Wall at "}, \mathrm{n2s}\left(\dfrac{FT_r}{L_{wall}}, 2\right), \text{", D.fill = "}, \mathrm{n2s}\left(\dfrac{\max\left(D_{fills}\right)}{ft}, 2\right), \text{"ft."}\right) \end{array} \right.$$

1	"GOV (row#)"	1
2	"VEH (#)"	iv
3	"VEH (name)"	$\mathrm{TRUCKS}_{iv,1}$
4	"TRUCK (#)"	1
5	"TRUCK mirror"	0
6	"TRUCK, (ft, kip)"	$\left(\mathrm{TRUCKS}_{iv,2}\right)_1$
7	"TRUCK (h.eq, 0, 0)"	$\left(\dfrac{h_{eq}}{ft} \quad 0 \quad 0\right)$
8	"LOC (inc)"	$\dfrac{FT_r}{L_{wall}}$
9	"LOC (ft)"	$\dfrac{FT_r}{ft}$
10	"TEST"	"M.wall"
11	"LOC message, Excel"	$\mathrm{MSSG}_{\mathrm{LOC}}$
12	"RF message"	$\mathrm{MSSG}_{\mathrm{RF}}$
13	"RF"	RF
14	"RATING (tons)"	$\mathrm{RF} \cdot \mathrm{GVW}_{iv,2}$
15	"LL/DL"	$\dfrac{\mathrm{GVW}_{iv,2}}{\mathrm{GVW}_{1,2}} \cdot \dfrac{LV_M + LS_{M_r}}{DC_M + EV_M + EH_{M_r}}$
16	"LOC message, CAD"	$\mathrm{concat}\left(\mathrm{n2s}\left(\dfrac{t_{slab} + h_{haunch.bot} + FT_r}{ft}, 2\right), \text{" from the bottom of the slab"}\right)$

```
RFs5EXTWALL := | for  iv ∈ 1 .. rows(TRUCKS)
               |   T^⟨iv⟩ ← RF_ExtWall(iv)^⟨3⟩
               | T^T
```

Top SLab Rating Factors (1 of 2)

RFpos(Mr, γDL, γLL) & RFneg(Mr, γDL, γLL) - rating factor equations for positive and negative loads

$$\mathrm{RFpos}(C, DL, LL) := \left| \begin{array}{l} \text{return } 99 \text{ if } LL < 0.001 \\ \min\left(99, \dfrac{C - DL}{LL}\right) \end{array} \right.$$

$$\mathrm{RFneg}(C, DL, LL) := \left| \begin{array}{l} \text{return } 99 \text{ if } LL > -0.001 \\ \min\left(99, \dfrac{C - DL}{LL}\right) \end{array} \right.$$

RFs1(iD) - run rating factors for one depth of fill

$$\mathrm{RFs1}(iD) := \left| \begin{array}{l} \gamma LL \leftarrow \gamma LLwLBL\left(D_{fills_{iD}}\right) \\ \text{for } iv \in 1..\mathrm{rows}(TRUCKS) \\ \quad \left| \begin{array}{l} RF_Mp(\gamma LLMp) \leftarrow RFpos\left(\dfrac{\psi\phi Mn}{kip \cdot ft}, \gamma DL_{iD,1}, \gamma LLMp\right) \\ RF_Mn(\gamma LLMn) \leftarrow RFneg\left(\dfrac{-\psi\phi Mn}{kip \cdot ft}, \gamma DL_{iD,2}, \gamma LLMn\right) \\ V(\gamma LLV, \gamma LLM) \leftarrow \left| \begin{array}{l} Mu \leftarrow \left(\gamma LLM + \gamma DL_{iD,4}\right) \cdot kip \cdot ft \\ Vu \leftarrow \left(\gamma LLV + \gamma DL_{iD,3}\right) \cdot kip \\ C \leftarrow \dfrac{-\psi\phi Vn\left(Mu, Vu, D_{fills_{iD}}\right)}{kip} \\ RFneg\left(C, \gamma DL_{iD,3}, \gamma LLV\right) \end{array} \right. \\ RF_{iv,1} \leftarrow \overrightarrow{RF_Mp\left(\gamma LL_{iv,2}\right)} \\ RF_{iv,2} \leftarrow \overrightarrow{RF_Mn\left(\gamma LL_{iv,3}\right)} \\ RF_{iv,3} \leftarrow \overrightarrow{V\left(\gamma LL_{iv,4}, \gamma LL_{iv,5}\right)} \end{array} \right. \\ \mathrm{augment}(\gamma LL, RF) \end{array} \right.$$

RFs2(iD) - run rating factors for one depth of fill, and report the governing row

$$\mathrm{RFs2}(iD) := \left| \begin{array}{l} T \leftarrow \mathrm{RFs1}(iD) \\ \text{for } iRF \in 1..3 \\ \quad \text{for } iv \in 1..\mathrm{rows}(TRUCKS) \\ \quad\quad \left| \begin{array}{l} minRF_{iv,iRF} \leftarrow \min\left(T_{iv,iRF+5}\right) \\ MATCH_{iv,iRF} \leftarrow \mathrm{match2}\left(minRF_{iv,iRF}, T_{iv,iRF+5}\right) \\ R_{iv,iRF} \leftarrow MATCH_{iv,iRF} \end{array} \right. \\ \mathrm{augment}(T, minRF, R) \end{array} \right.$$

γDFIMshow(iv, D, γLL) - show live load factors (γ.LL, DF, IM, and LL)

$$\gamma DFIMshow\left(iv, D_{fill}, \gamma LL\right) := \left| \begin{array}{l} (DF \quad IM) \leftarrow \left(\dfrac{ft}{Eeq\left(mpf_{iv}, D_{fill}\right)} \quad IMeq\left(D_{fill}\right)\right) \\ \mathrm{concat}\left(n2s\left(\gamma_{LL_{iv}}, 2\right), "*", n2s(DF, 4), "*", n2s(IM, 3), "*", n2s\left(\dfrac{\gamma LL}{\gamma_{LL_{iv}} \cdot DF \cdot IM}, 1\right)\right) \end{array} \right.$$

Top Slab Rating Factors (2 of 2)

RFdetails1(iv, MMV, DL, γDL, LL, γLL, C, RF, BrINC, D) - show rating factor details for one vehicle and one depth of fill

$$\text{RFdetails1}(iv, MMV, DL, \gamma DL, LL, \gamma LL, C, RF, BrINC, D) := \left|\begin{array}{l} MMV \leftarrow (\text{"M.pos"}\ \ \text{"M.neg"}\ \ \text{"V.neg"})_{1,MMV} \\ RFeq \leftarrow \text{concat}[\text{"RF = ("}, \text{n2s}(C,2), \text{" - "}, \text{n2s}(\gamma DL,2), \text{") / ("}, \gamma DFIMshow(iv,D,\gamma LL), \text{") = "}, (\text{n2s}(RF,2))] \\ LOC \leftarrow \text{concat}\left(\text{"Top Slab at "}, \text{n2s}(BrINC,2), \text{", D.fill = "}, \text{n2s}\left(\frac{D}{ft},2\right), \text{"ft."}\right) \\ \left(MMV\ \ LOC\ \ RFeq\ \ RF\ \ RF \cdot GVW_{iv,2}\ \ \frac{LL}{DL}\ \ \text{concat}\left(\text{n2s}\left(iioft(BrINC) + \frac{t_{ExtWall}}{ft},1\right), \text{"ft. to face of Ext Wall"}\right)\right) \end{array}\right.$$

RFs3(iD) - show rating factors for all vehicles, for depth of fill $D_{fills_{iD}}$

$$\text{RFs3}(iD) := \left|\begin{array}{l} T1 \leftarrow \text{RFs2}(iD) \\ T3 \leftarrow \text{matrix}(1,16,f(i,j) \leftarrow 0) \\ \text{for } iv \in 1..\text{rows}(TRUCKS) \\ \quad \text{for } MMV \in 1..3 \\ \quad\quad (ROW\ \ COL) \leftarrow \left[\left(T1_{iv,11+MMV}\right)\ \ (1)\right] \\ \quad\quad (DLt\ \ \gamma DLt\ \ LLt\ \ \gamma LLt) \leftarrow \left[\left(DL_{iD,MMV}\right)_{1,1}\ \ \left(\gamma DL_{iD,MMV}\right)_{1,1}\ \ \frac{\left(T1_{iv,1+MMV}\right)_{ROW}}{\gamma LL_eq(iv)}\ \ \left(T1_{iv,1+MMV}\right)_{ROW}\right] \\ \quad\quad C \leftarrow \left[\left(\frac{\psi\phi Mn}{kip \cdot ft}\right)\ \ \left(\frac{-\psi\phi Mn}{kip \cdot ft}\right)\ \ \left[\frac{-\psi\phi Vn\left[\left[\left(T1_{iv,5}\right)_{ROW} + \left(\gamma DL_{iD,4}\right)_{1,1}\right] \cdot kip \cdot ft\right], \left[\left[\left(T1_{iv,4}\right)_{ROW} + \left(\gamma DL_{iD,3}\right)_{1,1}\right] \cdot kip\right], D_{fills_{iD}}\right]}{kip}\right]\right]_{1,MMV} \\ \quad\quad T2 \leftarrow \text{RFdetails1}\left[iv, MMV, DLt, \gamma DLt, LLt, \gamma LLt, C, \left(T1_{iv,8+MMV}\right), RSIF_CHK_LOCS_{MMV,3}, D_{fills_{iD}}\right] \\ \quad\quad DET_LABEL \leftarrow \begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 \\ \text{"ROW\#"} & \text{"VEH\#"} & \text{"NAME"} & \text{"TRUCK\#"} & \text{"MIRROR"} & 0 & \text{"x1x2}\gamma\omega\text{"} \end{pmatrix} \\ \quad\quad DET \leftarrow \left(T1_{iv,1}^{\ T}\right)^{\langle ROW \rangle} \\ \quad\quad (DLt\ \ \gamma DLt) \leftarrow \left[\left[\left(DL_{iD,MMV}\right)_{1,COL}\right]\ \ \left[\left(\gamma DL_{iD,MMV}\right)_{1,COL}\right]\right] \\ \quad\quad (LLt\ \ \gamma LLt) \leftarrow \left[\left[\frac{IMeq\left(D_{fills_{iD}}\right) \cdot ft}{Eeq\left(mpf_{iv}, D_{fills_{iD}}\right)} \cdot INFx1x2\omega\left[(iMpos\ \ iMneg\ \ iVneg)_{1,MMV}, DET_7\right]\right]\ \ \left[\left(T1_{iv,1+MMV}\right)_{ROW,COL}\right]\right] \\ \quad\quad TRUCK \leftarrow \text{if}\left[DET_5 = 0, \left(TRUCKS_{iv,2}\right)_{DET_4}, MIRROR\left[\left(TRUCKS_{iv,2}\right)_{DET_4}\right]\right] \\ \quad\quad \left(DET_6\ \ DET_8\ \ DET_9\right) \leftarrow \left(TRUCK\ \ RSIF_CHK_LOCS_{MMV,3}\ \ RSIF_CHK_LOCS_{MMV,4}\right) \\ \quad\quad T3 \leftarrow \text{stack}\left(T3, \text{augment}\left(DET^T, T2\right)\right) \\ \text{submatrix}(T3,2,\text{rows}(T3),1,\text{cols}(T3)) \end{array}\right.$$

RFs5 - run all rating factors for all depths of fill, and stack on top of the exterior wall rating factors

$$\text{RFs5} := \left|\begin{array}{l} RFs4 \leftarrow \left|\begin{array}{l} \text{for } i \in 1..\text{rows}\left(D_{fills}\right) \\ \quad T1 \leftarrow \left|\begin{array}{l} \text{RFs3}(i)\ \ \text{if } i = 1 \\ \text{stack}(T1, \text{RFs3}(i))\ \ \text{otherwise} \end{array}\right. \\ T1 \end{array}\right. \\ (r\ \ RowsPerDfill) \leftarrow \left(0\ \ \frac{\text{rows}(RFs4)}{\text{rows}\left(D_{fills}\right)}\right) \\ \text{for } i \in 1..RowsPerDfill \\ \quad \text{for } iD \in 1..\text{rows}\left(D_{fills}\right) \\ \quad\quad \left|\begin{array}{l} r \leftarrow r + 1 \\ T2^{\langle r \rangle} \leftarrow \left(RFs4^T\right)^{\langle (iD-1) \cdot RowsPerDfill + i \rangle} \end{array}\right. \\ \text{stack}\left(T2^T, RFs5EXTWALL\right) \end{array}\right.$$

MAKE OUTPUT SUMMARIES

```
DESIGN_ROW_minRF(iv, MorV) := | (minRF  minRFrow) ← (999  1)
                              | for i ∈ 1..rows(RFs5)
                              |   if substr(RFs5[i,10], 0, 1) = MorV ∧ iv = RFs5[i,2]
                              |     | minRF ← min(minRF, RFs5[i,13])
                              |     | minRFrow ← i  if  minRF = RFs5[i,13]
                              | minRFrow
```

```
OUT_CAD := | DET(MorV) ← | for iv ∈ 1..rows(TRUCKS)
           |             |   T⟨iv⟩ ← | r ← DESIGN_ROW_minRF(iv, MorV)
           |             |           | (RFs5[r,15]  RFs5[r,13]  RFs5[r,14]  RFs5[r,11]  RFs5[r,16])^T
           |             | T
           | HDR ← ("LL/DL"  "RF"  "TONS"  "LOCATION"  "DIMENSION")
           | R1 ← augment[stack[("TEST:"  "VEH")^T, TRUCKS⟨1⟩], stack(matrix(1,5,f(i,j) ← "MOMENT"), HDR, DET("M")^T)]
           | R3 ← augment[stack[("TEST:"  "VEH")^T, TRUCKS⟨1⟩], stack(matrix(1,5,f(i,j) ← "SHEAR"), HDR, DET("V")^T)]
           | stack(R1, matrix(1,6,f(i,j) ← ""), R3)
```

```
OUT_Excel_Verbose := | for r ∈ 1..rows(RFs5)
                     |   T⟨r⟩ ← (RFs5[r,3]  RFs5[r,13]  RFs5[r,11]  RFs5[r,10]  RFs5[r,12])^T
                     | stack[("VEH"  "RF"  "LOCATION"  "TEST"  "RF.equation"), T^T]
```

```
RFsGOV := | row(iv) ← | (minRF  minRFrow) ← (999  1)
          |           | for i ∈ 1..rows(RFs5)
          |           |   if iv = RFs5[i,2]
          |           |     | minRF ← min(minRF, RFs5[i,13])
          |           |     | minRFrow ← i  if  minRF = RFs5[i,13]
          |           | minRFrow
          | for iv ∈ 1..rows(TRUCKS)
          |   T⟨iv⟩ ← | r ← row(iv)
          |           | (RFs5[r,3]  RFs5[r,13]  RFs5[r,11]  RFs5[r,10]  RFs5[r,12])^T
          | stack[("VEH"  "Gov.RF"  "Governing.LOCATION"  "Gov.TEST"  "Governing.RF.equation"), T^T]
```

SHOW DETAILED RESULTS

```
CHECKeq(iv) := | for MMVE ∈ 1..4
               |   | TEST ← ("M.pos" "M.neg" "V.neg" "M.wall")[1,MMVE]
               |   | RF ← 999
               |   | for i ∈ 1..rows(RFs5)
               |   |   if RFs5[i,13] ≤ RF ∧ RFs5[i,2] = iv ∧ RFs5[i,10] = TEST
               |   |     | RF ← RFs5[i,13]
               |   |     | T⟨MMVE⟩ ← (RFs5^T)⟨i⟩
               | T^T
```

```
CHECKallD(iv) := | c ← 0
                 | for MMVE ∈ 1..4
                 |   | TEST ← ("M.pos" "M.neg" "V.neg" "M.wall")[1,MMVE]
                 |   | for i ∈ 1..rows(RFs5)
                 |   |   if RFs5[i,2] = iv ∧ RFs5[i,10] = TEST
                 |   |     | c ← c + 1
                 |   |     | T⟨c⟩ ← (RFs5^T)⟨i⟩
                 | T^T
```

```
CHECK_DeGook(T) := | T ← augment(T⟨3⟩, T⟨6⟩, T⟨7⟩, submatrix(T,1,rows(T),10,12))
                   | for i ∈ 1..rows(T)
                   |   | T[i,2] ← stack[("ft" "kip"), T[i,2]]
                   |   | T[i,3] ← stack[("start(ft)" "end(ft)" "klf"), T[i,3]]
                   |   | T[i,5] ← (T[i,5] T[i,6])^T
                   | T[rows(T),3] ← [ "h.eq(ft)"  ""  ""
                   |                (T[rows(T),3])[2,1]  ""  "" ]
                   | submatrix(T,1,rows(T),1,5)
```

```
CHECKeq(iv) := CHECK_DeGook(CHECKeq(iv))
```

```
CHECKallD(iv) := CHECK_DeGook(CHECKallD(iv))
```

```
QCHECK := CHECKeq(testVEH)
```

Rating Factor Assembly (4 of 4)

RF TABLE, ALL TESTS AT THE GOVERNING FILL

```
RFs := | HDR ← ("+M.slab"  "-M.slab"  "V.slab"  "M.wall")
       | T1(iv) ← | for j ∈ 1..4
                  |   | RFt ← 999
                  |   | for i ∈ 1..rows(RFs5)
                  |   |   RFt ← min(RFt, RFs5[i,13])  if RFs5[i,2] = iv ∧ RFs5[i,10] = ("M.pos"  "M.neg"  "V.neg"  "M.wall")[1,j]
                  |   | RF[j] ← RFt
                  | RF^T
       | for iv ∈ 1..rows(TRUCKS)
       |   T2⟨iv⟩ ← T1(iv)^T
       | augment(AV2⟨2⟩, stack(HDR, T2^T))
```

RF & TONS, ALL TESTS AT THE GOVERNING FILL

```
TONS := | HDR ← ("+M.slab"  "-M.slab"  "V.slab"  "M.wall")
        | T1(iv) ← submatrix(RFs, iv + 1, iv + 1, 2, 5)·GVW[iv,2]
        | for iv ∈ 1..rows(TRUCKS)
        |   T2⟨iv⟩ ← T1(iv)^T
        | augment(AV2⟨2⟩, stack(HDR, T2^T))
```

```
RF_TN := | SUB(M) ← submatrix(M, 1, rows(M), 2, 5)
         | HDR(LBL) ← matrix(1, 4, f(i,j) ← LBL)
         | C1 ← stack[("VEH"  "VEH"  "VEH"), AV3]
         | C2 ← stack(HDR("RF"), SUB(RFs))
         | C3 ← stack(HDR("TON"), SUB(TONS))
         | augment(C1, C2)
```

EXPAND SUB-MATRICES FOR EXCEL OUTPUT

DeFunk1(M, Rows) - add some blank rows to matrix M

```
DeFunk1(M, Rows) := | S(r,c) ← matrix(r, c, f(i,j) ← "")
                    | rM ← rows(M)
                    | return stack[(M), S(Rows − 1, 1)]  if rM = 0
                    | return M  if rM = Rows
                    | stack(M, S(Rows − rows(M), cols(M)))
```

DeFunk2(M) - expand submatrices in matrix M with stack and augment

```
DeFunk2(M) := | for i ∈ 1..rows(M)
              |   for j ∈ 1..cols(M)
              |     T1[i] ← if(j = 1, M[i,1], augment(T1[i], M[i,j]))
              | for i ∈ 1..rows(T1)
              |   T2 ← if(i = 1, T1[1], stack(T2, T1[i]))
              | T2
```

DeFunk3 - governing details for one vehicle

```
DeFunk3(M) := | for itest ∈ 1..rows(M)
              |   | ROWS ← max(⃗rows(M^T))
              |   | for j ∈ 1..cols(M)
              |   |   T1[itest,j] ← DeFunk1(M[itest,j], ROWS)
              | DeFunk2(T1)
```

DeFunkCheck_4 - details for all vehicles and all fill depths

```
DeFunk4(M) := | for iv ∈ 1..rows(M)
              |   T ← | DeFunk3(M[iv])  if iv = 1
              |       | stack(T, DeFunk3(M[iv]))  otherwise
              | T
```

CHECK - details for testVEH at the governing fill depths

```
CHECK := DeFunk3(CHECKeq(testVEH))
```

Details_Verbose - details for all vehicles and all fill depths

```
OUT_Verbose := DeFunk4(⃗CHECKallD(AV⟨1⟩))
```

Prepare Export to Excel

$$\text{Description} := \begin{bmatrix} \text{"Bridge No"} & \text{BridgeNo} \\ \text{"Name"} & \text{BridgeName} \\ \text{"Description"} & \text{BridgeDescription} \\ \text{"Method"} & \begin{pmatrix} \text{"LFR - Load Factor"} \\ \text{"LRFR-LRFD"} \end{pmatrix}_{\text{LRFR}+1} \\ \text{"Impact"} & \left| \begin{array}{l} n \leftarrow \text{search}\left(\text{RFsGOV}_{3,3}, \text{"D.fill"}, 1\right) \\ \left(\text{IMeq}\left(\text{str2num}\left(\text{substr}\left(\text{RFsGOV}_{3,3}, n+9, 4\right)\right) \cdot \text{ft}\right) - 1\right) \end{array} \right. \\ \text{"Span Length"} & L_1 \end{bmatrix} = \begin{pmatrix} \text{"Bridge No"} & \text{"999999"} \\ \text{"Name"} & \text{"CR123 over Culvert Ck"} \\ \text{"Description"} & \text{"Index 6037 Triple 10x10, 1958"} \\ \text{"Method"} & \text{"LRFR-LRFD"} \\ \text{"Impact"} & 0.25 \\ \text{"Span Length"} & 10.83 \end{pmatrix}$$

$$\text{NULL}(r, c) := \text{matrix}(r, c, f(i, j) \leftarrow \text{""})$$

$$\text{maxROWS_maxCOLS}(\text{Matrices}) := \left| \begin{array}{l} \text{mx}(M) \leftarrow \max(M) \\ \left(\text{mx}\left(\overrightarrow{\text{rows}(\text{Matrices})}\right) \quad \text{mx}\left(\overrightarrow{\text{cols}(\text{Matrices})}\right)\right) \end{array} \right.$$

AugmentFill(Names, Matrices) - combine Matrices, horizontal direction

$$\text{AugmentFill}(\text{Names}, \text{Matrices}) := \left| \begin{array}{l} \text{MaxRows} \leftarrow \text{maxROWS_maxCOLS}(\text{Matrices})_{1,1} \\ \text{STACK}(\text{Matrix}) \leftarrow \text{Matrix} \ \ \text{on error} \ \ \text{stack}(\text{Matrix}, \text{NULL}(\text{MaxRows} - \text{rows}(\text{Matrix}), \text{cols}(\text{Matrix}))) \\ \text{for} \ \ i \in 1..\text{rows}(\text{Matrices}) \\ \quad \left| \begin{array}{l} \text{HEADER} \leftarrow \text{Names}_i \ \ \text{on error} \ \ \text{augment}\left(\text{Names}_i, \text{NULL}\left(1, \text{cols}\left(\text{Matrices}_i\right) - 1\right)\right) \\ \text{T} \leftarrow \text{stack}\left(\text{HEADER}, \text{STACK}\left(\text{Matrices}_i\right)\right) \ \ \text{on error} \ \ \text{augment}\left(\text{T}, \text{NULL}(\text{MaxRows} + 1, 1), \text{stack}\left(\text{HEADER}, \text{STACK}\left(\text{Matrices}_i\right)\right)\right) \end{array} \right. \\ \text{T} \end{array} \right.$$

StackFill(Names, Matrices) - combine Matrices, vertical direction

$$\text{StackFill}(\text{Names}, \text{Matrices}) := \left| \begin{array}{l} \text{MaxCols} \leftarrow \text{maxROWS_maxCOLS}(\text{Matrices})_{1,2} \\ \text{AUGMENT}(\text{Matrix}) \leftarrow \text{augment}(\text{Matrix}, \text{NULL}(\text{rows}(\text{Matrix}), \text{MaxCols} - \text{cols}(\text{Matrix}) + 1)) \\ \text{for} \ \ i \in 1..\text{rows}(\text{Matrices}) \\ \quad \left| \begin{array}{l} \text{HEADER} \leftarrow \text{augment}\left(\text{Names}_i, \text{NULL}(1, \text{MaxCols})\right) \\ \text{T} \leftarrow \text{stack}\left(\text{HEADER}, \text{AUGMENT}\left(\text{Matrices}_1\right)\right) \ \ \text{on error} \ \ \text{stack}\left(\text{T}, \text{NULL}(1, \text{MaxCols} + 1), \text{HEADER}, \text{AUGMENT}\left(\text{Matrices}_i\right)\right) \end{array} \right. \\ \text{T} \end{array} \right.$$

WRITE_DATA_TO_EXCEL(Name_of_Worksheet) - write all output matrices to one Excel sheet. Use Excel formulas to link that data to secondary sheets formatted for printing. To force Excel formula updating, apply a VBA macro: Private Sub Workbook_Open(), Application.CalculateFull, End Sub.

$$\text{WRITE_DATA_TO_EXCEL}(\text{Name_of_Worksheet}) := \left| \begin{array}{l} \text{Worksheet} \leftarrow \text{Name_of_Worksheet} \\ \text{WRITEEXCEL}(\text{matrix}(500, 50, f(i, j) \leftarrow \text{""}), \text{Worksheet}, \text{"DATA!A1"}) \\ \text{WRITEEXCEL}\left[\text{AugmentFill}\left[\begin{pmatrix} \text{"Decription"} \\ \text{"RFs"} \\ \text{"RFs.GOV"} \\ \text{"RFs.VERBOSE"} \\ \text{"CAD"} \end{pmatrix}, \begin{pmatrix} \text{Description} \\ \text{RFs} \\ \text{RFsGOV} \\ \text{OUT_Verbose} \\ \text{OUT_CAD} \end{pmatrix}\right], \text{Worksheet}, \text{"DATA!A1"}\right] \end{array} \right.$$

Quick Check Setup (1 of 2)

MAKE INFLUENCE MATRIX, AND ASSIGN RF CHECK OUTPUTS

$RF_Mpos := \left(QCHECK^T\right)^{\langle 1\rangle^T}$ $RF_Mneg := \left(QCHECK^T\right)^{\langle 2\rangle^T}$ $RF_Vneg := \left(QCHECK^T\right)^{\langle 3\rangle^T}$ $RF_ExtWall := \left(QCHECK^T\right)^{\langle 4\rangle^T}$

$ips := 20$ $RSIF_check := RSIF_{eq}\left(L, BrIncs_{eq2}(L, ips)\right)$ $INF2_check := INF2_{eq}(L, RSIF_check)$

$ROWS := RSIF_check^{\langle 1\rangle}$ $BrINCS := RSIF_check^{\langle 3\rangle}$ $FT := RSIF_check^{\langle 4\rangle} \cdot ft$ $TK := TRUCKS_{testVEH,1}$

$(MpCol \;\; MnCol \;\; VnCol) := \left(match2\left(pM_{BrINC}, RSIF_check^{\langle 3\rangle}\right) \;\; match\left(2.00, RSIF_check^{\langle 3\rangle}\right)_1 \;\; match2\left(Vinc, RSIF_check^{\langle 3\rangle}\right)\right) = (10 \;\; 25 \;\; 21)$

$Mpos := \left(INF2_check_{1,1}\right)^{\langle MpCol\rangle} \cdot \frac{kip \cdot ft}{kip}$ $Mneg := \left(INF2_check_{1,1}\right)^{\langle MnCol\rangle} \cdot \frac{kip \cdot ft}{kip}$ $Vneg := \left(INF2_check_{1,4}\right)^{\langle VnCol\rangle} \cdot \frac{kip}{kip}$ $Mv := \left(INF2_check_{1,1}\right)^{\langle VnCol\rangle} \cdot \frac{kip \cdot ft}{kip}$

$\gamma LL_{show}\left(\gamma_{LL}, DF, IM, LL\right) := concat\left["(", n2s\left(\gamma_{LL}, 2\right), ")(", n2s(DF, 4), ")(1+", n2s[(IM - 1) \cdot 100, 0], "\%)(", n2s(LL, 1), ") = ", n2s\left(\gamma_{LL} \cdot DF \cdot IM \cdot LL, 2\right)\right]$ - show live load

STATE VARIABLES COMMON TO ALL RF CHECKS FOR TEST VEHICLE TK = "HL93.OPR"

$$Dfilleq(CHK) := \left| \begin{array}{l} T \leftarrow \left(CHK_{1,5}\right)_1 \\ (start \;\; end) \leftarrow (search(T, "=", 1) \;\; search(T, "ft", 1)) \\ str2num(substr(T, start + 1, end - start - 1)) \cdot ft \end{array} \right.$$

Dfilleq(CHK) - extract depth of fill from a check output

$mpf := mpf_{testVEH}$

$mpf = 1.20$ - single-lane multiple presence factor

$\gamma_{LL} := \gamma LL_{testVEH} = 1.35$

$\gamma_{LL} = 1.35$ - live load factor

Quick Check Setup (2 of 2)

MAKE PLOTS

PLTCIRCLE(r, θ) - plot a circle: r - radius, θ - starting angle

$$\text{PLTCIRCLE}(r,\theta) := \left| \begin{array}{l} \text{for } i \in 1..13 \\ \quad \left| \begin{array}{l} \theta 2 \leftarrow \theta + \frac{360\text{deg}}{12}\cdot(i-1) \\ \left(T_{i,1} \;\; T_{i,2}\right) \leftarrow r\cdot(\cos(\theta 2) \;\; \sin(\theta 2)) \end{array} \right. \\ T \end{array} \right.$$

PLTAXL(x, r, P, CIRCLE) - plot an axle weight P at location x

$$\text{PLTAXL}(x,r,P,\text{CIRCLE}) := \left| \begin{array}{l} \text{Scale} \leftarrow 0.1768\cdot\sqrt{P} \\ \text{CIRCLE} \leftarrow \text{CIRCLE}\cdot\text{Scale} \\ \text{augment}\left(\text{CIRCLE}^{\langle 1\rangle} + x, \text{CIRCLE}^{\langle 2\rangle} + r\cdot\text{Scale}\right) \end{array} \right.$$

PLTaxles(TKr, TRKdist, D) - plot the truck axles, and scale for size

$$\text{PLTaxles}(\text{TKr},\text{TRKdist},D) := \left| \begin{array}{l} \text{CIRCLE} \leftarrow \text{PLTCIRCLE}(18\text{in}, -90\text{deg}) \\ \text{AXL}(x,P) \leftarrow \text{PLTAXL}(x, 18\text{in}, P, \text{CIRCLE}) \\ x \leftarrow \min\left(\text{TRKdist}^{\langle 1\rangle}\right)\cdot\text{ft} + 0.5\cdot\left(D\cdot\text{DF}_{\text{earth}} + \text{tire}_{\text{length}}\right) \\ \text{TRKraw} \leftarrow \text{MIRROR}(\text{TKr}) \\ T \leftarrow \text{AXL}\left(x, \text{TRKraw}_{1,2}\right) \\ \text{for } i \in 1..\text{rows}(\text{TRKraw}) \\ \quad \left| \begin{array}{l} x \leftarrow x + \text{TRKraw}_{i,1}\cdot\text{ft} \\ T \leftarrow \left| \begin{array}{l} T \;\; \text{if } i = 1 \\ \text{stack}\left(T, \text{AXL}\left(x, \text{TRKraw}_{i,2}\right)\right) \;\; \text{otherwise} \end{array} \right. \end{array} \right. \\ T^{\langle 2\rangle} \leftarrow T^{\langle 2\rangle} + D \\ T \end{array} \right.$$

PLTdist(TKd, D) - plot longitudinal distribution

$$\text{PLTdist}(\text{TKd},D) := \left| \begin{array}{l} \text{Side} \leftarrow 0.5\cdot D\cdot\text{DF}_{\text{earth}} \\ \text{PLT1DIST}(x1,x2) \leftarrow \begin{pmatrix} x1+\text{Side} & D \\ x1 & 0 \\ x1+\text{Side} & D \\ x2-\text{Side} & D \\ x2 & 0 \\ x2-\text{Side} & D \end{pmatrix} \\ T \leftarrow \text{PLT1DIST}\left(\text{TKd}_{1,1}\cdot\text{ft}, \text{TKd}_{1,2}\cdot\text{ft}\right) \\ \text{return } T \;\; \text{if } \text{rows}(\text{TKd}) = 1 \\ \text{for } i \in 2..\text{rows}(\text{TKd}) \\ \quad T \leftarrow \text{stack}\left(T, \text{PLT1DIST}\left(\text{TKd}_{i,1}\cdot\text{ft}, \text{TKd}_{i,2}\cdot\text{ft}\right)\right) \\ T \end{array} \right.$$

PLTTRK(CHECK) - plot axles and longitudinal distribution for a RF check output, which contains details for the governing location

$$\text{PLTTRK}(\text{CHECK}) := \left| \begin{array}{l} D \leftarrow \text{Dfilleq}(\text{CHECK}) \\ (T1 \;\; T2) \leftarrow \left(\text{CHECK}_{1,2} \;\; \text{CHECK}_{1,3}\right) \\ (\text{TRKraw} \;\; \text{TRKdist}) \leftarrow (\text{submatrix}(T1,2,\text{rows}(T1),1,2) \;\; \text{submatrix}(T2,2,\text{rows}(T2),1,2)) \\ (\text{PLTaxles} \;\; \text{PLTdist}) \leftarrow (\text{PLTaxles}(\text{TRKraw},\text{TRKdist},D) \;\; \text{PLTdist}(\text{TRKdist},D)) \\ \text{TRUCK} \leftarrow \text{stack}(\text{PLTdist},\text{PLTaxles})\cdot\text{ft}^{-1} \\ \text{range} \leftarrow \max\left(\text{TRUCK}^{\langle 1\rangle}, \sum L\cdot 1.1\right) - \min\left(\text{TRUCK}^{\langle 1\rangle}, -0.1\cdot\sum L\right) \\ \text{PlotRatio} \leftarrow 3 \\ (\text{Xmin} \;\; \text{Xmax} \;\; \text{Ymax}) \leftarrow \left[\left(\min\left(\text{TRUCK}^{\langle 1\rangle} - \frac{\text{range}}{10}, -0.1\cdot\sum L\right)\right) \;\; \left(\max\left(\text{TRUCK}^{\langle 1\rangle} + \frac{\text{range}}{10}, \sum L\cdot 1.1\right)\right) \;\; \left(\frac{\text{range}}{\text{PlotRatio}} - 2\right)\right] \\ \text{ROAD} \leftarrow \text{augment}\left(\text{ROAD}^{\langle 1\rangle}, \text{ROAD}^{\langle 2\rangle} - \max\left(\text{ROAD}^{\langle 2\rangle}\right) + D\cdot\text{ft}^{-1}\right) \\ \text{if } \text{Ymax} < 1.1\cdot\max\left(\text{TRUCK}^{\langle 2\rangle}\right) \\ \quad \left| \begin{array}{l} \Delta Y \leftarrow 1.1\cdot\max\left(\text{TRUCK}^{\langle 2\rangle}\right) - \text{Ymax} \\ (\text{range} \;\; \text{Xmin} \;\; \text{Xmax} \;\; \text{Ymax}) \leftarrow \left[(\text{range} + \text{PlotRatio}\cdot\Delta Y) \;\; \left(\text{Xmin} - \frac{\text{PlotRatio}}{2}\cdot\Delta Y\right) \;\; \left(\text{Xmax} + \frac{\text{PlotRatio}}{2}\cdot\Delta Y\right) \;\; (\text{Ymax} + \Delta Y)\right] \end{array} \right. \\ (\text{range} \;\; \text{Xmin} \;\; \text{Xmax} \;\; \text{Ymax} \;\; \text{TRUCK} \;\; \text{ROAD}) \end{array} \right.$$

EXPAND THIS AREA TO PRINT

Results

Z := WRITE_DATA_TO_EXCEL("FDOT Hinged-End Culvert (2016 04-12).xlsm") - output to Excel, to a sheet named DATA.

RF_TN =

"VEH"	"VEH"	"VEH"	"RF"	"RF"	"RF"	"RF"
"VEH"	"mpf"	"γ.LL"	"+M.slab"	"-M.slab"	"V.slab"	"M.wall"
"HL93.INV"	1.20	1.75	0.85	1.09	1.08	1.41
"HL93.OPR"	1.20	1.35	1.10	1.42	1.54	1.83
"FL120"	1.00	1.35	0.88	1.02	1.30	1.32
"SU2"	1.00	1.35	2.15	2.74	3.73	4.66
"SU3"	1.00	1.35	1.54	1.58	2.28	2.40
"SU4"	1.00	1.35	1.74	1.81	2.62	2.26
"C3"	1.00	1.35	2.04	2.42	3.69	2.83
"C4"	1.00	1.35	1.50	2.05	2.39	2.16
"C5"	1.00	1.35	1.61	1.92	2.62	1.98
"ST5"	1.00	1.35	1.84	2.04	2.87	1.98

$$\begin{pmatrix} \gamma_{DCmin} \\ \gamma_{DCmax} \\ \eta\gamma_{EVmin} \\ \eta\gamma_{EVmax} \\ \eta\gamma_{EHmin} \\ \eta\gamma_{EHmax} \end{pmatrix} = \begin{pmatrix} 0.90 \\ 1.25 \\ 0.90 \\ 1.37 \\ 0.90 \\ 1.42 \end{pmatrix}$$

RFsGOV =

"VEH"	"Gov.RF"	"Governing.LOCATION"	"Gov.TEST"	"Governing.RF.equation"
"HL93.INV"	0.85	"Top Slab at 1.40, D.fill = 1.90ft."	"M.pos"	"RF = (20.46 - 4.46) / (1.75* 0.1304*1.252*65.8) = 0.85"
"HL93.OPR"	1.10	"Top Slab at 1.40, D.fill = 1.90ft."	"M.pos"	"RF = (20.46 - 4.46) / (1.35* 0.1304*1.252*65.8) = 1.10"
"FL120"	0.88	"Top Slab at 1.40, D.fill = 1.90ft."	"M.pos"	"RF = (20.46 - 4.46) / (1.35* 0.1087*1.252*98.6) = 0.88"
"SU2"	2.15	"Top Slab at 1.40, D.fill = 1.90ft."	"M.pos"	"RF = (20.46 - 4.46) / (1.35* 0.1087*1.252*40.6) = 2.15"
"SU3"	1.54	"Top Slab at 1.40, D.fill = 1.90ft."	"M.pos"	"RF = (20.46 - 4.46) / (1.35* 0.1087*1.252*56.6) = 1.54"
"SU4"	1.74	"Top Slab at 1.40, D.fill = 1.90ft."	"M.pos"	"RF = (20.46 - 4.46) / (1.35* 0.1087*1.252*50.0) = 1.74"
"C3"	2.04	"Top Slab at 1.40, D.fill = 1.90ft."	"M.pos"	"RF = (20.46 - 4.46) / (1.35* 0.1087*1.252*42.7) = 2.04"
"C4"	1.50	"Top Slab at 1.40, D.fill = 1.90ft."	"M.pos"	"RF = (20.46 - 4.46) / (1.35* 0.1087*1.252*58.3) = 1.50"
"C5"	1.61	"Top Slab at 1.40, D.fill = 1.90ft."	"M.pos"	"RF = (20.46 - 4.46) / (1.35* 0.1087*1.252*54.1) = 1.61"
"ST5"	1.84	"Top Slab at 1.40, D.fill = 1.90ft."	"M.pos"	"RF = (20.46 - 4.46) / (1.35* 0.1087*1.252*47.4) = 1.84"

CHECK =

"HL93.OPR"	"ft"	"kip"	"start(ft)"	"end(ft)"	"klf"	"M.pos"	"Top Slab at 1.40, D.fill = 1.90ft."
""	0.00	25.00	5.83	8.85	1.83	""	"RF = (20.46 - 4.46) / (1.35* 0.1304*1.252*65.8) = 1.10"
""	4.00	25.00	1.83	4.85	1.83	""	""
""	""	""	""	""	""	""	""
"HL93.OPR"	"ft"	"kip"	"start(ft)"	"end(ft)"	"klf"	"M.neg"	"Top Slab at 2.00, D.fill = 1.90ft."
""	0.00	8.00	30.56	33.57	0.58	""	"RF = (-20.46 - -5.57) / (1.35* 0.1304*1.252*-47.6) = 1.42"
""	14.00	32.00	16.56	19.57	2.34	""	""
""	14.00	32.00	2.56	5.57	2.34	""	""
"HL93.OPR"	"ft"	"kip"	"start(ft)"	"end(ft)"	"klf"	"V.neg"	"Top Slab at 1.90, D.fill = 1.90ft."
""	0.00	25.00	6.63	9.65	1.83	""	"RF = (-13.57 - -2.55) / (1.35* 0.1304*1.252*-32.5) = 1.54"
""	4.00	25.00	2.63	5.65	1.83	""	""
""	""	""	""	""	""	""	""
"HL93.OPR"	"ft"	"kip"	"h.eq(ft)"	""	""	"M.wall"	"Ext Wall at 0.48, D.fill = 2.60ft."
""	0.00	8.00	2.57	""	""	""	"RF = [1.75/1.35][1.20/1.20][36/36][(12.10 - 7.52) / (3.24)] = 1.83"
""	14.00	32.00	""	""	""	""	""
""	14.00	32.00	""	""	""	""	""

Quick Check (1 of 8), Positive Moment

$$RF_Mpos = \left[\text{"HL93.OPR"} \quad \begin{pmatrix} \text{"ft"} & \text{"kip"} \\ 0.00 & 25.00 \\ 4.00 & 25.00 \end{pmatrix} \begin{pmatrix} \text{"start(ft)"} & \text{"end(ft)"} & \text{"klf"} \\ 5.83 & 8.85 & 1.83 \\ 1.83 & 4.85 & 1.83 \end{pmatrix} \quad \text{"M.pos"} \quad \begin{pmatrix} \text{"Top Slab at 1.40, D.fill = 1.90ft."} \\ \text{"RF = (20.46 - 4.46) / (1.35* 0.1304*1.252*65.8) = 1.10"} \end{pmatrix} \right]$$

$$\psi c\phi Mn := \psi_c \cdot 0.90 \cdot f_y \cdot A_s \cdot \left(d - \frac{1}{2} \cdot \frac{f_y \cdot A_s}{0.85 \cdot f_c \cdot 12in} \right)$$

$\psi c\phi Mn = 20.46 \cdot kip \cdot ft$ - factored capacity; $\psi_c = 1.00$, $d = 8.62 \cdot in$, $A_s = 0.845 \cdot in^2$

$$D_{fill} := Dfilleq(RF_Mpos)$$

$D_{fill} = 1.90\,ft$ - depth of fill, roadway surface to top of top slab

$$F_e := \min\left(1.15, 1 + 0.20 \cdot \frac{D_{fill}}{\sum L \cdot ft + t_{ExtWall}}\right)$$

$F_e = 1.011$ - earth interaction factor

$$\gamma\omega DLmax := \gamma_{DCmax} \cdot t_{slab} \cdot 150pcf \cdot ft + F_e \cdot \eta\gamma_{EVmax} \cdot D_{fill} \cdot 120pcf \cdot ft$$

$\gamma\omega DLmax = 0.475 \cdot klf$ - maximum factored DL, $\gamma_{DCmax} = 1.25$ $\eta\gamma_{EVmax} = 1.37$

$$\gamma DL_{pM} := \int_{0ft}^{\sum L\,ft} linterp(FT, Mpos, x) \cdot \gamma\omega DLmax \, dx$$

$\gamma DL_{pM} = 4.46 \cdot kip \cdot ft$ - factored dead load

$$DF := LLDFeq(mpf, D_{fill})$$

$DF = 0.1304$ - live load distribution factor, axles per strip foot

$$IM := IMeq(D_{fill})$$

$IM = 1.252$ - dynamic impact factor

$$E_{long} := DF_{earth} \cdot D_{fill} + tire_{length}$$

$E_{long} = 3.02\,ft$ - longitudinal distribution, where $DF_{earth} = 1.15$ $tire_{length} = 10.00 \cdot in$

$$x\omega := submatrix\left(RF_Mpos_{1,3}, 2, rows\left(RF_Mpos_{1,3}\right), 1, 3\right)$$

$$start := x\omega^{\langle 1 \rangle} \cdot ft = \begin{pmatrix} 5.8 \\ 1.8 \end{pmatrix} ft \qquad end := x\omega^{\langle 2 \rangle} \cdot ft = \begin{pmatrix} 8.8 \\ 4.8 \end{pmatrix} ft \qquad \omega := \frac{x\omega^{\langle 3 \rangle} \cdot klf}{\gamma_{LL} \cdot DF \cdot IM} = \begin{pmatrix} 8.28 \\ 8.28 \end{pmatrix} \cdot klf$$

$$LL_{pM} := \sum \overrightarrow{\left(\omega \cdot \int_{start}^{end} \max(linterp(FT, Mpos, x), 0 \cdot klf) \, dx \right)}$$

$LL_{pM} = 65.9 \cdot kip \cdot ft$ - raw live load (no γ_{LL}, no DF, no IM)

$$\gamma LL_{show}\left(\gamma_{LL}, DF, IM, \frac{LL_{pM}}{kip \cdot ft}\right) = \text{"(1.35)(0.1304)(1+25.\%)(65.9) = 14.52"}$$

$$\left(\psi c\phi Mn \quad \gamma DL_{pM} \quad \gamma_{LL} \cdot DF \cdot IM \cdot LL_{pM}\right) = (20.46 \quad 4.46 \quad 14.52) \cdot kip \cdot ft$$

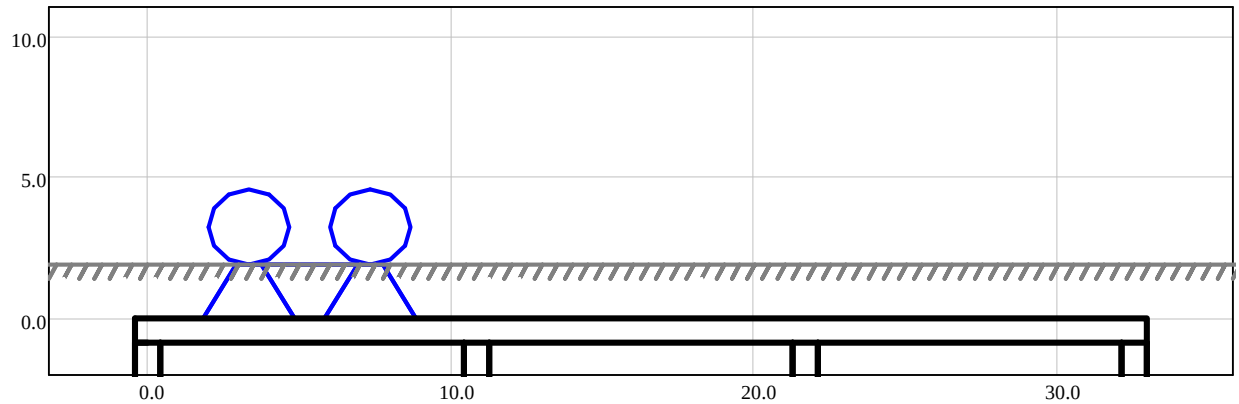
$$\frac{\psi c\phi Mn - \gamma DL_{pM}}{\gamma_{LL} \cdot DF \cdot IM \cdot LL_{pM}} = 1.10$$

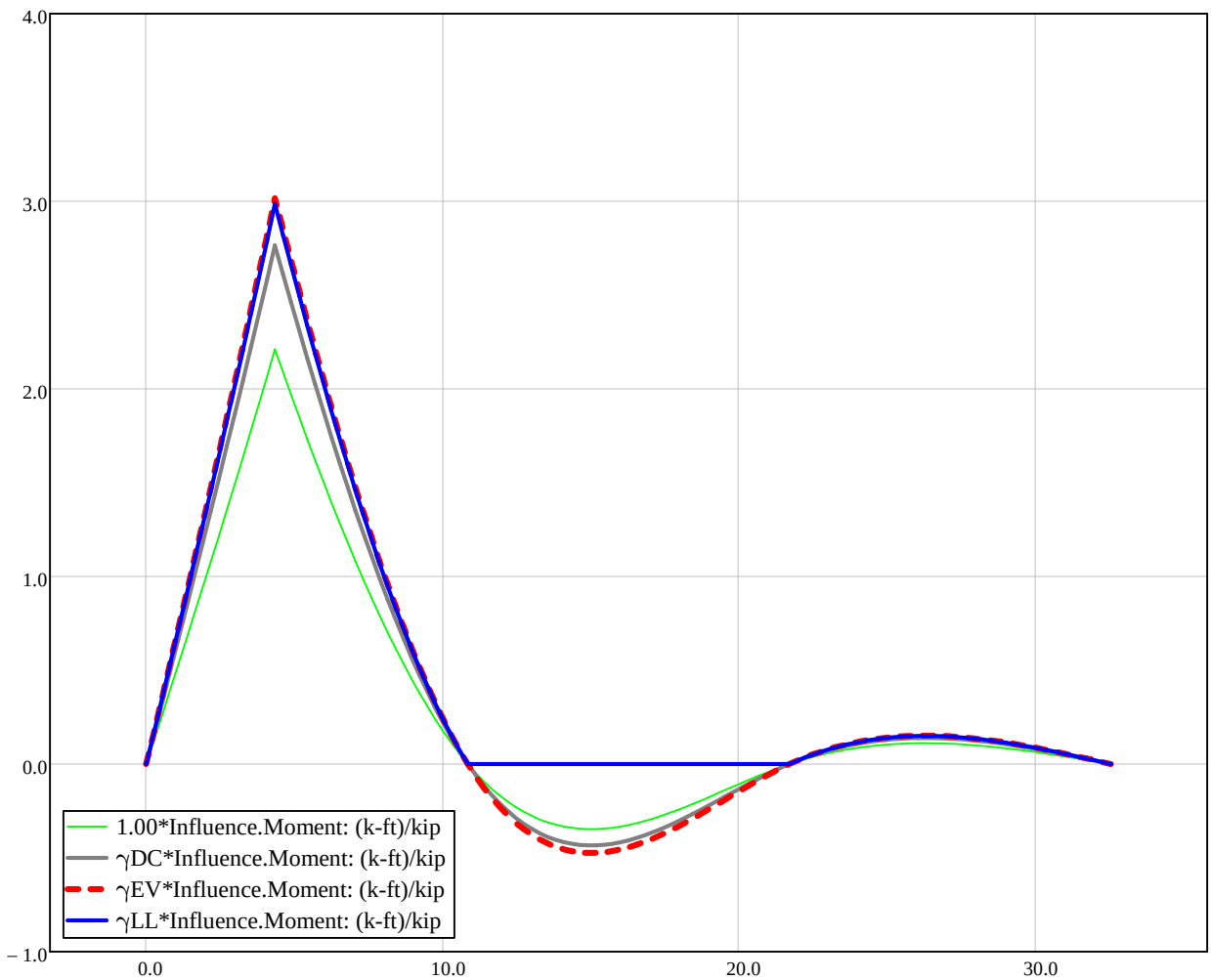
Unfactored ratio LL/DL: $LL := DF \cdot IM \cdot LL_{pM} = 10.75 \cdot kip \cdot ft$ and $DL := \left(DL_{match}\left(D_{fill}, D_{fills}\right)_{1,1}\right)_1 \cdot kip \cdot ft = 3.37\,ft \cdot kip$, so $= \frac{LL}{DL} = 3.19$

Quick Check (2 of 8), Positive Moment Plot

$$RF_Mpos = \begin{bmatrix} \text{"HL93.OPR"} & \begin{pmatrix} \text{"ft"} & \text{"kip"} \\ 0.00 & 25.00 \\ 4.00 & 25.00 \end{pmatrix} & \begin{pmatrix} \text{"start(ft)"} & \text{"end(ft)"} & \text{"klf"} \\ 5.83 & 8.85 & 1.83 \\ 1.83 & 4.85 & 1.83 \end{pmatrix} & \text{"M.pos"} & \begin{pmatrix} \text{"Top Slab at 1.40, D.fill = 1.90ft."} \\ \text{"RF = (20.46 - 4.46) / (1.35* 0.1304*1.252*65.8) = 1.10"} \end{pmatrix} \end{bmatrix}$$

PLT_truck := PLTTRK(RF_Mpos)





Quick Check (3 of 8), Negative Moment

$$RF_Mneg = \left[\text{"HL93.OPR"} \quad \begin{pmatrix} \text{"ft"} & \text{"kip"} \\ 0.00 & 8.00 \\ 14.00 & 32.00 \\ 14.00 & 32.00 \end{pmatrix} \begin{pmatrix} \text{"start(ft)"} & \text{"end(ft)"} & \text{"klf"} \\ 30.56 & 33.57 & 0.58 \\ 16.56 & 19.57 & 2.34 \\ 2.56 & 5.57 & 2.34 \end{pmatrix} \quad \text{"M.neg"} \quad \begin{pmatrix} \text{"Top Slab at 2.00, D.fill = 1.90ft."} \\ \text{"RF = (-20.46 - -5.57) / (1.35* 0.1304*1.252*-47.6) = 1.42"} \end{pmatrix} \right]$$

$\psi c\phi Mn := -\psi c\phi Mn$

$\psi c\phi Mn = -20.46 \cdot kip \cdot ft$ - factored capacity; $\psi_c = 1.00$, $d = 8.62 \cdot in$, $A_s = 0.845 \cdot in^2$

$D_{fill} := Dfilleq(RF_Mneg)$

$D_{fill} = 1.90\,ft$ - depth of fill, roadway surface to top of top slab

$$F_e := \min\left(1.15, 1 + 0.20 \cdot \frac{D_{fill}}{\sum L \cdot ft + t_{ExtWall}}\right)$$

$F_e = 1.011$ - earth interaction factor

$\gamma\omega DLmax := \gamma_{DCmax} \cdot t_{slab} \cdot 150pcf \cdot ft + F_e \cdot \eta\gamma_{EVmax} \cdot D_{fill} \cdot 120pcf \cdot ft$

$\gamma\omega DLmax = 0.475 \cdot klf$ - max factored dead load, $\gamma_{DCmax} = 1.25$ $\eta\gamma_{EVmax} = 1.37$

$$\gamma DL_{nM} := \int_{0ft}^{\sum L\,ft} linterp(FT, Mneg, x) \cdot \gamma\omega DLmax\, dx$$

$\gamma DL_{nM} = -5.56 \cdot kip \cdot ft$ - factored dead load

$DF := LLDFeq(mpf, D_{fill})$

$DF = 0.1304$ - live load distribution factor, axles per strip foot

$IM := IMeq(D_{fill})$

$IM = 1.252$ - dynamic impact factor

$E_{long} := DF_{earth} \cdot D_{fill} + tire_{length}$

$E_{long} = 3.02\,ft$ - longitudinal distribution, where $DF_{earth} = 1.15$ $tire_{length} = 10.00 \cdot in$

$$x\omega := submatrix(RF_Mneg_{1,3}, 2, rows(RF_Mneg_{1,3}), 1, 3)$$

$$start := x\omega^{\langle 1 \rangle} \cdot ft = \begin{pmatrix} 30.6 \\ 16.6 \\ 2.6 \end{pmatrix} ft \qquad end := x\omega^{\langle 2 \rangle} \cdot ft = \begin{pmatrix} 33.6 \\ 19.6 \\ 5.6 \end{pmatrix} ft \qquad \omega := \frac{x\omega^{\langle 3 \rangle} \cdot klf}{\gamma_{LL} \cdot DF \cdot IM} = \begin{pmatrix} 2.65 \\ 10.60 \\ 10.60 \end{pmatrix} \cdot klf$$

$$LL_{nM} := \sum \overrightarrow{\left(\omega \cdot \int_{start}^{end} \min(linterp(FT, Mneg, x), 0 \cdot klf)\, dx\right)}$$

$LL_{nM} = -47.6 \cdot kip \cdot ft$ - raw live load (no γ_{LL}, no DF, no IM)

$$\gamma LL_{show}\left(\gamma_{LL}, DF, IM, \frac{LL_{nM}}{kip \cdot ft}\right) = \text{"(1.35)(0.1304)(1+25.\%)(-47.6) = -10.48"}$$

$$\left(\psi c\phi Mn \quad \gamma DL_{nM} \quad \gamma_{LL} \cdot DF \cdot IM \cdot LL_{nM}\right) = (-20.46 \quad -5.56 \quad -10.48) \cdot kip \cdot ft$$

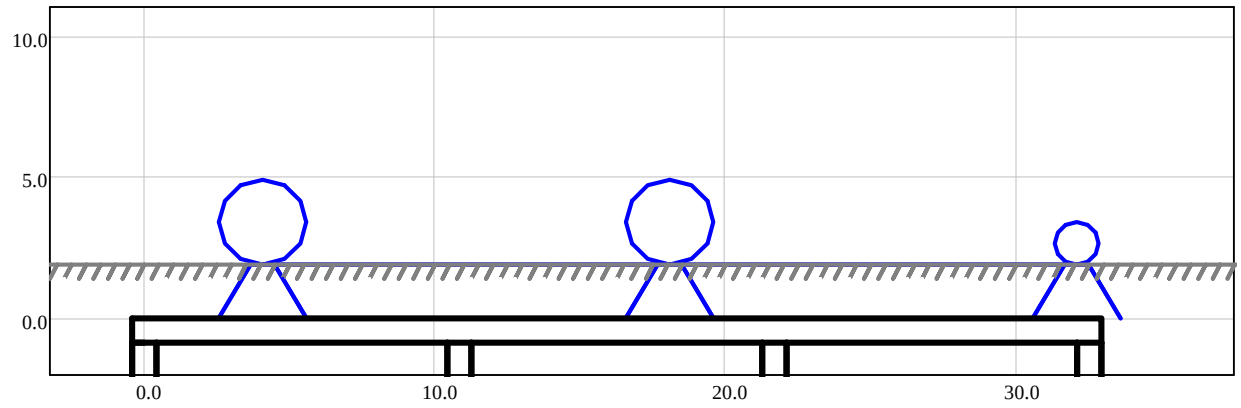
$$\frac{\psi c\phi Mn - \gamma DL_{nM}}{\gamma_{LL} \cdot DF \cdot IM \cdot LL_{nM}} = 1.42$$

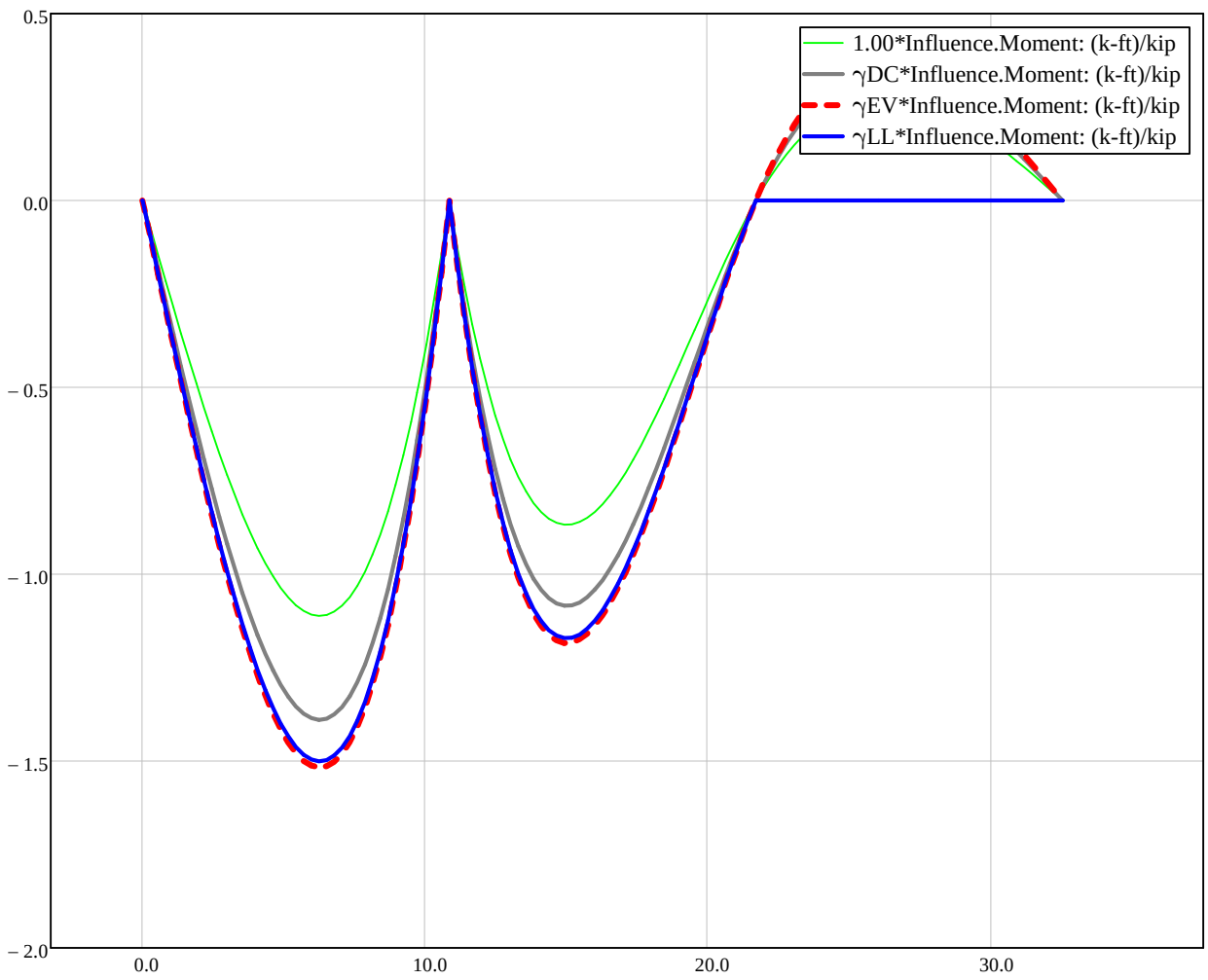
Unfactored ratio LL/DL: $LL := DF \cdot IM \cdot LL_{nM} = -7.76 \cdot kip \cdot ft$ and $DL := \left(DL_{match}(D_{fill}, D_{fills})_{1,2}\right)_1 \cdot kip \cdot ft = -4.21\,ft \cdot kip$, so $= \frac{LL}{DL} = 1.85$

Quick Check (4 of 8), Negative Moment Plot

$$RF_Mneg = \left[\begin{array}{c} \text{"HL93.OPR"} \\ \\ \end{array} \begin{pmatrix} \text{"ft"} & \text{"kip"} \\ 0.00 & 8.00 \\ 14.00 & 32.00 \\ 14.00 & 32.00 \end{pmatrix} \begin{pmatrix} \text{"start(ft)"} & \text{"end(ft)"} & \text{"klf"} \\ 30.56 & 33.57 & 0.58 \\ 16.56 & 19.57 & 2.34 \\ 2.56 & 5.57 & 2.34 \end{pmatrix} \begin{array}{c} \text{"M.neg"} \\ \\ \end{array} \begin{pmatrix} \text{"Top Slab at 2.00, D.fill = 1.90ft."} \\ \text{"RF = (-20.46 - -5.57) / (1.35* 0.1304*1.252*-47.6) = 1.42"} \end{pmatrix} \right]$$

PLT_truck := PLTTRK(RF_Mneg)





Quick Check (5 of 8), Shear

$$RF_Vneg = \left[\text{"HL93.OPR"} \quad \begin{pmatrix} \text{"ft"} & \text{"kip"} \\ 0.00 & 25.00 \\ 4.00 & 25.00 \end{pmatrix} \begin{pmatrix} \text{"start(ft)"} & \text{"end(ft)"} & \text{"klf"} \\ 6.63 & 9.65 & 1.83 \\ 2.63 & 5.65 & 1.83 \end{pmatrix} \quad \text{"V.neg"} \quad \begin{pmatrix} \text{"Top Slab at 1.90, D.fill = 1.90ft."} \\ \text{"RF = (-13.57 - -2.55) / (1.35* 0.1304*1.252*-32.5) = 1.54"} \end{pmatrix} \right]$$

$$D_{fill} := Dfilleq(RF_Vneg) = 1.90\,ft \qquad F_e := \min\left(1.15, 1 + 0.20 \cdot \frac{D_{fill}}{\sum L \cdot ft + t_{ExtWall}}\right) = 1.011 \qquad COINC(Vneg, \gamma MAX, \gamma MIN) := if(Vneg < 0, \gamma MAX, \gamma MIN)$$

$$\gamma DLM := \int_0^{\sum L \cdot ft} linterp(FT, \gamma_{DCmax} \cdot Mv, x) \cdot (t_{slab} \cdot 150pcf \cdot ft) + linterp(FT, \eta\gamma_{EVmax} \cdot Mv, x) \cdot (F_e \cdot D_{fill} \cdot 120pcf \cdot ft)\, dx \qquad \gamma DLM = -2.36 \cdot kip \cdot ft$$

$$\gamma DLV := \int_0^{\sum L \cdot ft} linterp(FT, \gamma_{DCmax} \cdot Vneg, x) \cdot (t_{slab} \cdot 150pcf \cdot ft) + linterp(FT, \eta\gamma_{EVmax} \cdot Vneg, x) \cdot (F_e \cdot D_{fill} \cdot 120pcf \cdot ft)\, dx \qquad \gamma DLV = -2.55 \cdot kip$$

$$\gamma_{LL} = 1.35 \qquad mpf := mpf_eq(testVEH) = 1.20 \qquad DF := LLDFeq(mpf, D_{fill}) = 0.1304 \qquad IM := IMeq(D_{fill}) = 1.252$$

$$x\omega := submatrix(RF_Vneg_{1,3}, 2, rows(RF_Vneg_{1,3}), 1, 3) \qquad start := x\omega^{\langle 1 \rangle} \cdot ft = \begin{pmatrix} 6.63 \\ 2.63 \end{pmatrix} ft \qquad end := x\omega^{\langle 2 \rangle} \cdot ft = \begin{pmatrix} 9.65 \\ 5.65 \end{pmatrix} ft \qquad \omega := \frac{x\omega^{\langle 3 \rangle} \cdot klf}{\gamma_{LL} \cdot DF \cdot IMeq(D_{fill})} = \begin{pmatrix} 8.28 \\ 8.28 \end{pmatrix} \cdot klf$$

$$LL_M := \left| \begin{array}{l} McoincVLL \leftarrow \overrightarrow{COINC(Vneg, Mv, 0 \cdot Mv)} \\ \sum \overrightarrow{\left(\omega \cdot \int_{start}^{end} linterp(FT, McoincVLL, x)\, dx\right)} \end{array} \right. = -8.58 \cdot kip \cdot ft \qquad \gamma LL_M := \gamma_{LL} \cdot DF \cdot IM \cdot LL_M = -1.89 \cdot kip \cdot ft \qquad Mu := \gamma DLM + \gamma LL_M = -4.25 \cdot kip \cdot ft$$

$$LL_V := \left| \begin{array}{l} VnegLL \leftarrow \overrightarrow{COINC(Vneg, Vneg, 0 \cdot Vneg)} \\ \sum \overrightarrow{\left(\omega \cdot \int_{start}^{end} linterp(FT, VnegLL, x)\, dx\right)} \end{array} \right. = -32.52 \cdot kip \qquad \gamma LL_V := \gamma_{LL} \cdot DF \cdot IM \cdot LL_V = -7.17 \cdot kip \qquad Vu := \gamma DLV + \gamma LL_V = -9.72 \cdot kip$$

$$Vn_{DeepFill} := -\min\left(\max\left(2.5 \cdot \sqrt{f_c \cdot psi}, 2.14 \cdot \sqrt{f_c \cdot psi} + 4600 \cdot psi\, \rho \cdot \min\left(1, \frac{|Vu| \cdot d}{|Mu|}\right)\right), 4.0 \cdot \sqrt{f_c \cdot psi}\right) \cdot (ft \cdot d) = -16.02 \cdot kip \qquad \rho = 0.0082 \qquad d = 8.62 \cdot in$$

$$Vn_{LFR_ShallowFill} := -\min\left(1.9 \cdot \sqrt{\frac{f_c}{psi}} + 2500\rho \cdot \min\left(1, \frac{|Vu| \cdot d}{|Mu|}\right), 3.5 \cdot \sqrt{\frac{f_c}{psi}}\right) \cdot ft \cdot d \cdot psi = -12.88 \cdot kip \qquad f_c = 3.0 \cdot ksi$$

$$Vn_{LRFR_ShallowFill} := \frac{-4.8}{1 + 750 \cdot \dfrac{\max\left(\dfrac{A_s \cdot f_y}{Mn} \cdot |Mu|, |Vu|\right) + |Vu|}{29000ksi \cdot A_s}} \cdot \frac{51in}{39in + \max\left(12in, d_v \cdot \dfrac{1.38in}{0.375in + 0.63in}\right)} \cdot \left[\sqrt{f_c \cdot psi} \cdot ft \cdot \left(d - \frac{1}{2} \cdot \frac{f_y \cdot A_s}{0.85 \cdot f_c \cdot 12in}\right)\right] = -15.97 \cdot kip$$

$$\psi c\phi Vn := \left| \begin{array}{l} \text{return } \psi_c \cdot 0.85 \cdot Vn_{DeepFill} \text{ if } D_{fill} \ge 2ft \\ \text{return } \psi_c \cdot 0.85 \cdot Vn_{LFR_ShallowFill} \text{ if } LRFR = 0 \\ \psi_c \cdot 0.85 \cdot Vn_{LRFR_ShallowFill} \end{array} \right. \qquad \gamma LL_{show}\left(\gamma_{LL}, DF, IM, \frac{LL_V}{kip}\right) = \text{"(1.35)(0.1304)(1+25.\%)(-32.5) = -7.17"}$$

$$\left(\psi c\phi Vn \quad \gamma DLV \quad \gamma_{LL} \cdot DF \cdot IM \cdot LL_V\right) = (-13.57 \quad -2.55 \quad -7.17) \cdot kip \qquad \frac{\psi c\phi Vn - \gamma DLV}{\gamma_{LL} \cdot DF \cdot IM \cdot LL_V} = 1.54$$

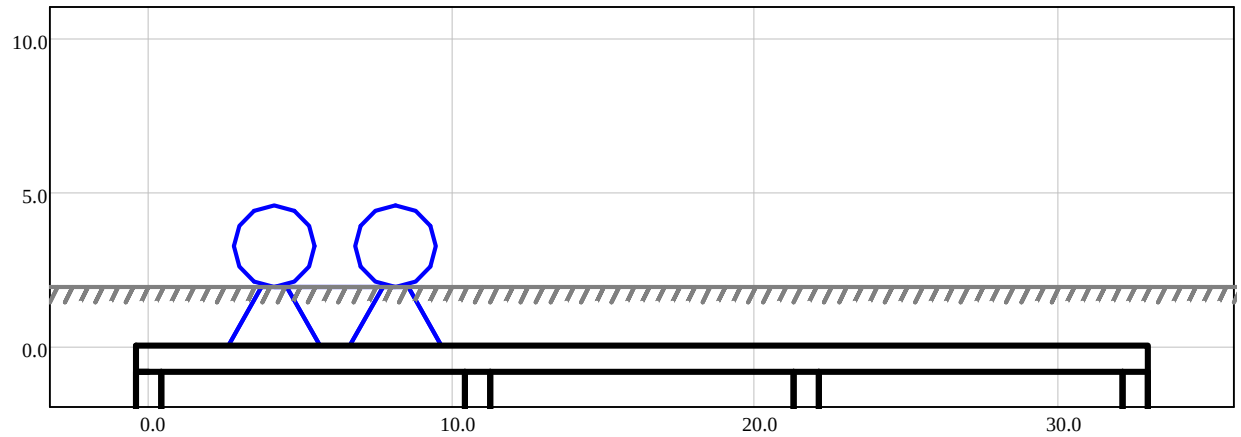
Unfactored ratio LL/DL: $LL := DF \cdot IM \cdot LL_V = -5.31 \cdot kip$ and $DL := \left(DL_{match}(D_{fill}, D_{fills})_{1,3}\right)_1 \cdot kip = -1.92 \cdot kip$, so $= \dfrac{LL}{DL} = 2.76$

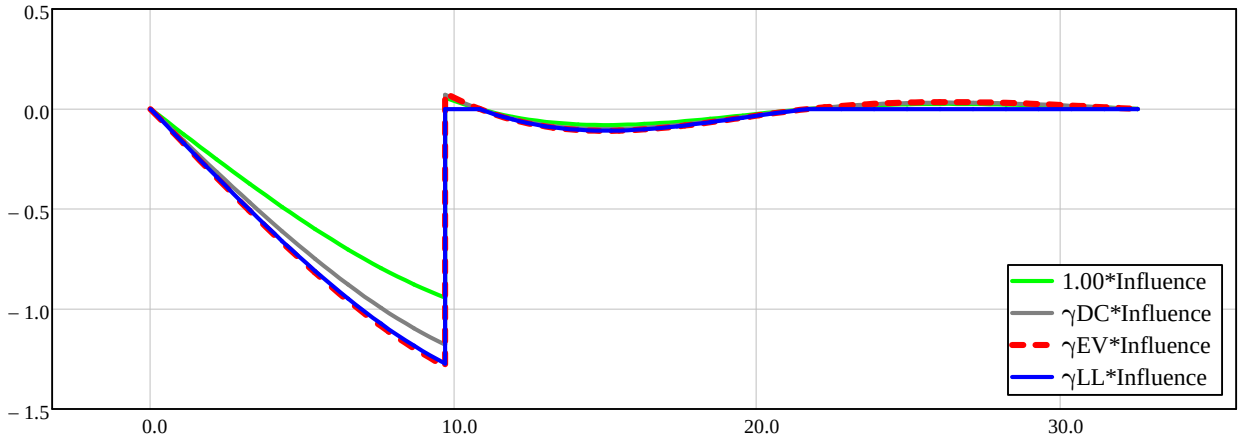
Quick Check (6 of 8), Shear Plots

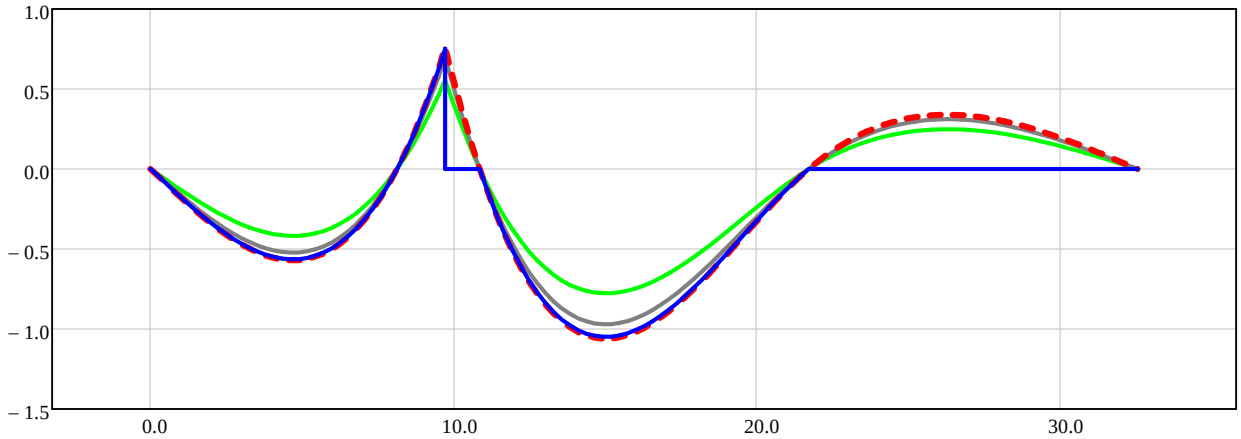
$$RF_Vneg = \begin{bmatrix} \text{"HL93.OPR"} & \begin{pmatrix} \text{"ft"} & \text{"kip"} \\ 0.00 & 25.00 \\ 4.00 & 25.00 \end{pmatrix} & \begin{pmatrix} \text{"start(ft)"} & \text{"end(ft)"} & \text{"klf"} \\ 6.63 & 9.65 & 1.83 \\ 2.63 & 5.65 & 1.83 \end{pmatrix} & \text{"V.neg"} & \begin{pmatrix} \text{"Top Slab at 1.90, D.fill = 1.90ft."} \\ \text{"RF = (-13.57 - -2.55) / (1.35* 0.1304*1.252*-32.5) = 1.54"} \end{pmatrix} \end{bmatrix}$$

PLT_truck := PLTTRK(RF_Vneg)

For LRFR, neglect live load not contributing to the force under consideration ($\gamma_{LL.LRFR.min} = 0$). Meanwhile for LFR, apply all axles.







Quick Check (7 of 8), Exterior Wall

$$RF_ExtWall = \left[\text{"HL93.OPR"} \quad \begin{pmatrix} \text{"ft"} & \text{"kip"} \\ 0.00 & 8.00 \\ 14.00 & 32.00 \\ 14.00 & 32.00 \end{pmatrix} \begin{pmatrix} \text{"h.eq(ft)"} & \text{""} & \text{""} \\ 2.57 & \text{""} & \text{""} \end{pmatrix} \quad \text{"M.wall"} \quad \begin{pmatrix} \text{"Ext Wall at 0.48, D.fill = 2.60ft."} \\ \text{"RF = [1.75/1.35][1.20/1.20][36/36][(12.10 - 7.52) / (3.24)] = 1.83"} \end{pmatrix} \right]$$

$D_{fill} := \max(D_{fills}) = 2.60\,ft$

$F_e := \min\left(1.15, 1 + 0.20 \cdot \frac{D_{fill}}{\sum L \cdot ft + t_{ExtWall}}\right) = 1.016$

$\gamma_{soil} = 120 \cdot pcf$

$INF_\omega := (0.5 \quad 0.375 \quad 0.4 \quad 0.3928)_{1, \min(4, cells)} \cdot L_1 \cdot ft = 4.333 \cdot \frac{kip}{klf}$ - axial force onto wall from uniform DL on top slab

$A_{s.wall} = 0.50 \cdot in^2$

$INF_P := (0 \quad 0.096 \quad 0.080)_{1, \min(3, cells)} = 0.080 \cdot \frac{kip}{kip}$ - uplifting axial force onto wall from point load on top slab

$f_y = 40 \cdot ksi$

$\gamma P_{DC} := -\gamma_{DCmin} \cdot (150pcf \cdot t_{slab} \cdot ft) \cdot INF_\omega = -0.50 \cdot kip$

$\gamma P_{EV} := -\eta \gamma_{EVmin} \cdot (F_e \cdot \gamma_{soil} \cdot D_{fill} \cdot ft) \cdot INF_\omega = -1.24 \cdot kip$

$f_c = 3.0 \cdot ksi$

$P_{LL} := 32kip$ $\quad DF := LLDFeq(mpf_eq(1), D_{fill}) = 0.1141$ $\quad IM := IMeq(D_{fill}) = 1.223$ $\quad \gamma P_{LV} := \gamma_{LL.Inventory} \cdot DF \cdot IM \cdot P_{LL} \cdot INF_P = 0.63 \cdot kip$

$F_{s.wall} := A_{s.wall} \cdot f_y = 19.84 \cdot kip$ $\quad a := \frac{F_{s.wall} + \gamma P_{DC} + \gamma P_{EV} + \gamma P_{LV}}{0.85 \cdot f_c \cdot ft} = 0.61 \cdot in$ $\quad M_arm := \frac{d_{wall}}{2} - \frac{a}{2} = 3.91 \cdot in$ - axial force to CG comp.

$h_{abutment} := D_{fill} + 2 \cdot t_{slab} + h_{clear} = 14.31\,ft$ $\quad h_{LL.surcharge} := h_{eq.equation}(h_{abutment}) = 2.57\,ft$ - LL surcharge

$x_{origin} := D_{fill} + t_{slab} + h_{clear} - h_{haunch.bot} = 13.12\,ft$ $\quad ix := 1, 2 .. 41$ $\quad x_{ix} := L_{wall} \cdot \frac{ix - 1}{40}$

$$\gamma EH := \left| \begin{array}{l} \omega_{EH}(x) \leftarrow \eta \gamma_{EHmax} \cdot \frac{\gamma_{soil}}{2} \cdot (x_{origin} - x) \cdot ft \\ \hline \int_0^x \int_0^{L_{wall}} \frac{\omega_{EH}(x) \cdot (L_{wall} - x)}{L_{wall}} dx - \int_0^x \omega_{EH}(x)\, dx\, dx \end{array} \right. \rightarrow$$

$$\gamma LS := \left| \begin{array}{l} \omega_{LH}(x) \leftarrow \gamma_{LL.Inventory} \cdot \frac{\gamma_{soil}}{2} \cdot h_{eq} \cdot ft \\ \hline \int_0^x \int_0^{L_{wall}} \frac{\omega_{LH}(x) \cdot (L_{wall} - x)}{L_{wall}} dx - \int_0^x \omega_{LH}(x)\, dx\, dx \end{array} \right. \rightarrow$$

$\psi\phi Mn_{wall} := \psi_c \cdot 0.90 \cdot A_{s.wall} \cdot f_y \cdot \left(d_{wall} - \frac{a}{2}\right) = 12.10 \cdot kip \cdot ft$

$\gamma DC := \gamma P_{DC} \cdot M_arm = -0.163 \cdot kip \cdot ft$ - factored component slab load, axial compression (-) reduces moment

$\gamma EV := \gamma P_{EV} \cdot M_arm = -0.403 \cdot kip \cdot ft$ - factored vertical earth load, axial compression (-) reduces moment

γEH: $\max(\gamma EH) = 8.10 \cdot kip \cdot ft$ - maximum factored horizontal earth (+) increases moment

$\gamma LV := \gamma P_{LV} \cdot M_arm = 0.204 \cdot kip \cdot ft$ - factored vertical LL, uplift for multi-cell CBCs, axial tension (+) increases moment

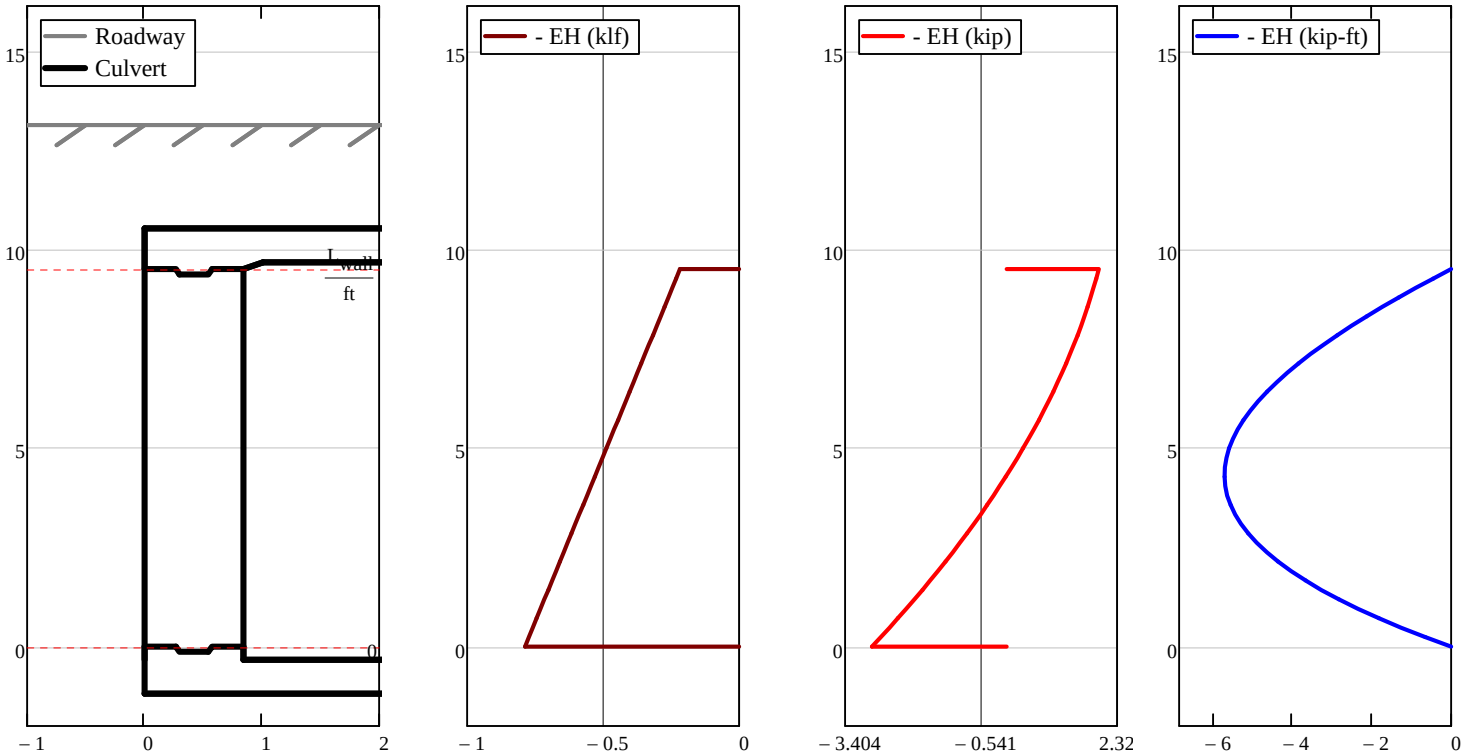
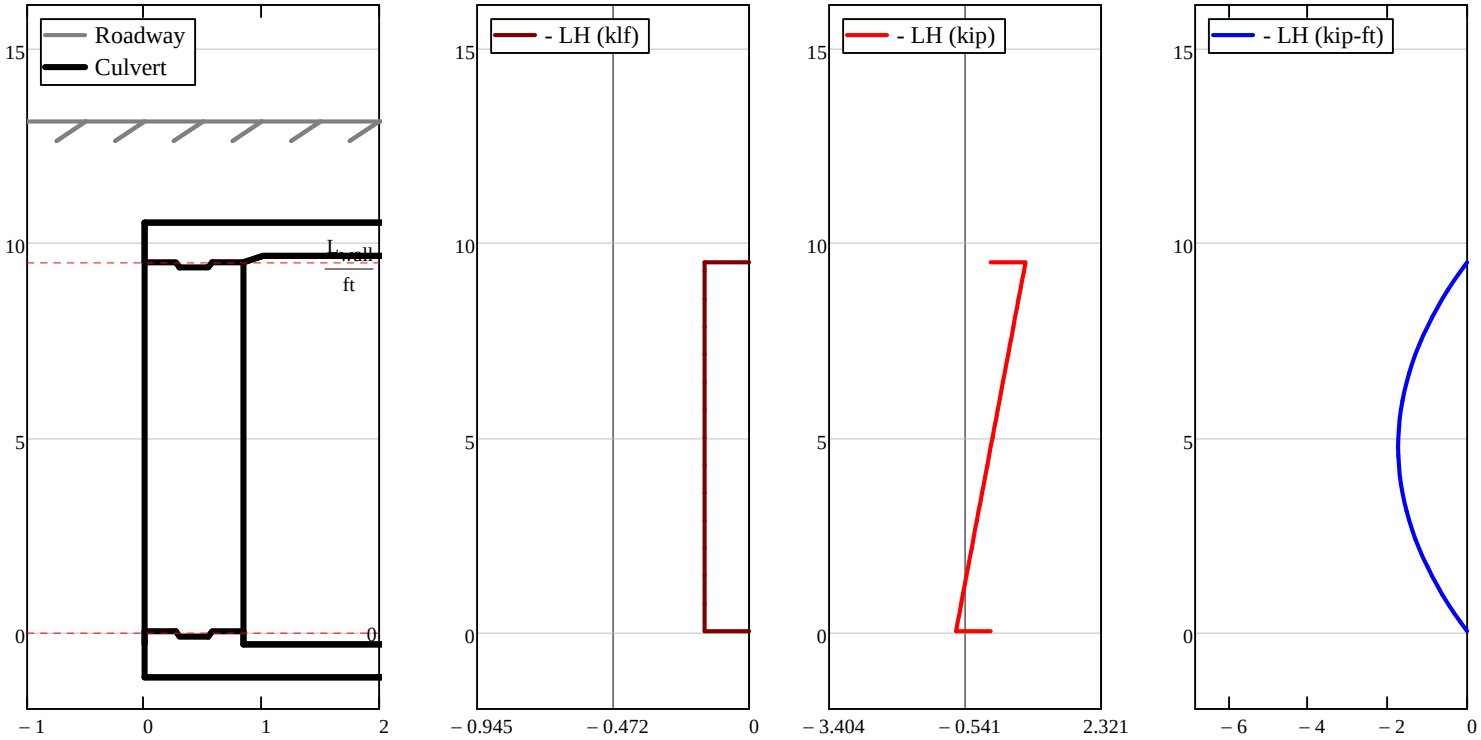
γLS: $\max(\gamma LS) = 3.04 \cdot kip \cdot ft$ - maximum factored LL surcharge (+) increases moment

$RF_{Inv} := \frac{\psi\phi Mn_{wall} - (\gamma DC + \gamma EV + \gamma EH)}{\gamma LV + \gamma LS}$ $\quad r := match(\min(RF_{Inv}), RF_{Inv})_1 = 20$ $\quad RF := \frac{\gamma_{LL.Inventory}}{\gamma_{LL}} \cdot \frac{mpf_eq(1)}{mpf} \cdot \frac{36}{GVW_{testVEH,2}} \cdot RF_{Inv_r}$ $\quad RF = 1.83$

$\left[\psi\phi Mn_{wall} \quad \left((\gamma DC + \gamma EV + \gamma EH_r)\right) \quad \max(\gamma LV + \gamma LS_r)\right] = (12.10 \quad 7.52 \quad 3.24) \cdot kip \cdot ft$ $\quad \gamma_{LL} = 1.35$ $\quad mpf_eq(1) = 1.20$ $\quad mpf = 1.20$ $\quad GVW_{testVEH,2} = 36$

Quick Check (8 of 8), Exterior Wall Plots

Horizontal Earth Load (EH)



Horizontal Live Load with Impact (LH)