DESIGN COMPUTATIONS FOR

VT Route 73 Bridge No. 13
28' x 10' Archcon with Anchor Wingwalls
Load Rating
Rochester, VT

PREPARED FOR:

Michie Corporation
PO Box 870
Henniker, New Hampshire 03242

STATE OF VERMONT
DARYL D. BURNS
No. 6331
Structural I
LICENSED
PROFESSIONAL ENGINEER
1/9/15

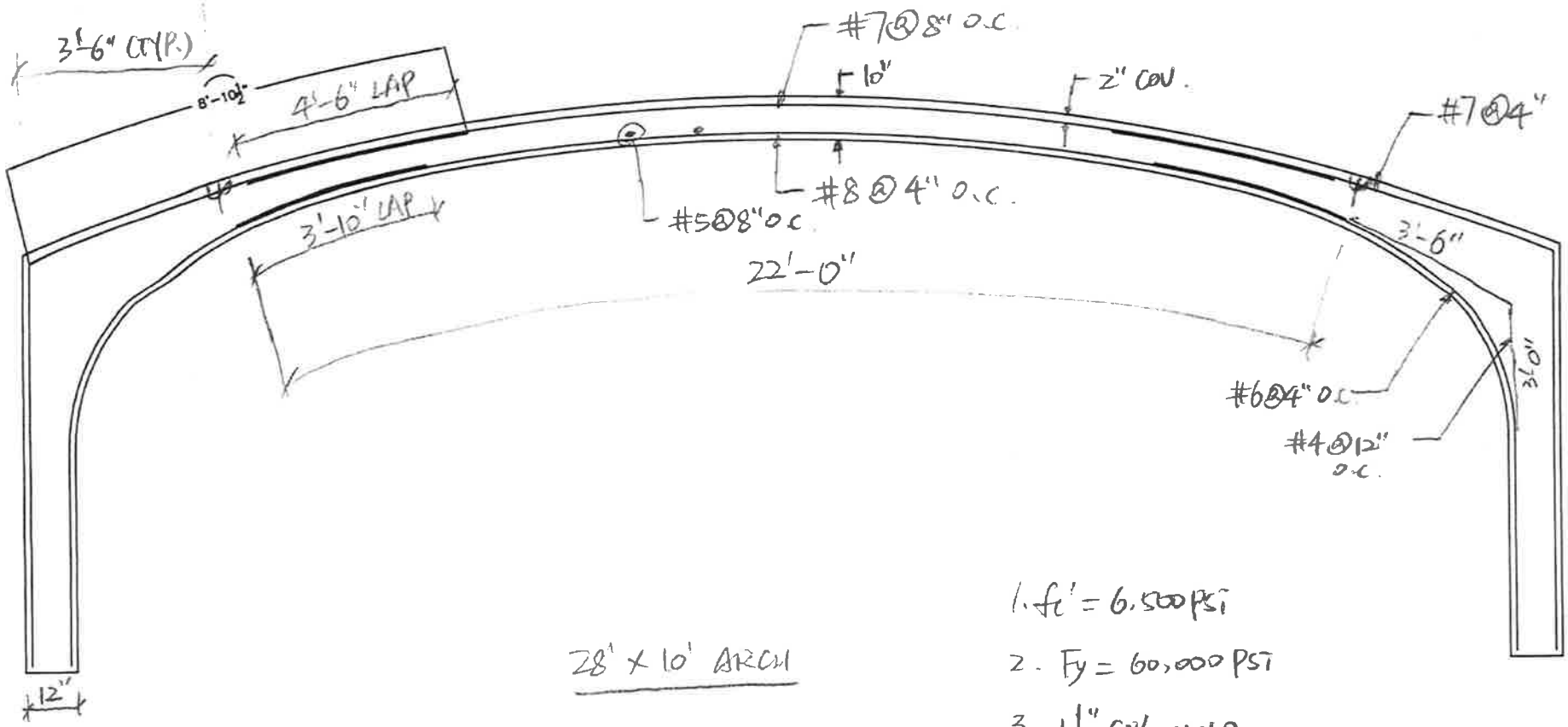
PREPARED BY:

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, New York 13760
TEL: 607-231-6600 FAX: 607-231-6650
EMAIL: precast@deltaengineers.com
www.deltaengineers.com

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch LRFR Load Rating		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING FACTORS							
LOADING LEVELS	TRUCK						
	H-20	HL-93	3S2	6 AXLE	3A STR.	4A STR.	5A SEMI
TONNAGE	20	36	36	66	30	35	38
INVENTORY	1.58	1.00					
POSTING							
OPERATING	2.04	1.294	3.275	1.551	2.19	1.94	3.08



28' x 10' ARCH

1. $f_c' = 6{,}500$ PSI
2. $F_y = 60{,}000$ PSI
3. $1\frac{1}{2}$" COV. UNO
4. PROVIDE #4 @ 12" O.C. LONGITUDINAL REINFORCING UNO.

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

2014.059.004 Rochester V 28x10

JOB	2014.059.004		3
DESCRIPTION	28 x 10 ARCH		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	3/12/2014
CHECKED BY	SLV	DATE	3/20/14

AN ISO 9001:2008 CERTIFIED COMPANY

REV. YL. 11/24/2014

28' x 10' ARCH DESIGN

FILL HT. 0' - 2'. USE LIVE LOAD FOR 0' FILL W/ 2' FILL HT FOR DESIGN.

ASSUME CONSTRUCTION VEHICLE NOT GREATER THAN HL-93.

$\eta = 1.05$ FOR NON-LIVE LOAD.

LOAD FACTORS FOR CANDE INPUT:

LOAD STEP 1 - DC . $1.25 \times 1.05 = 1.31$

LOAD STEP 2-4 - EH : $0.9 / 1.05 = 0.857$

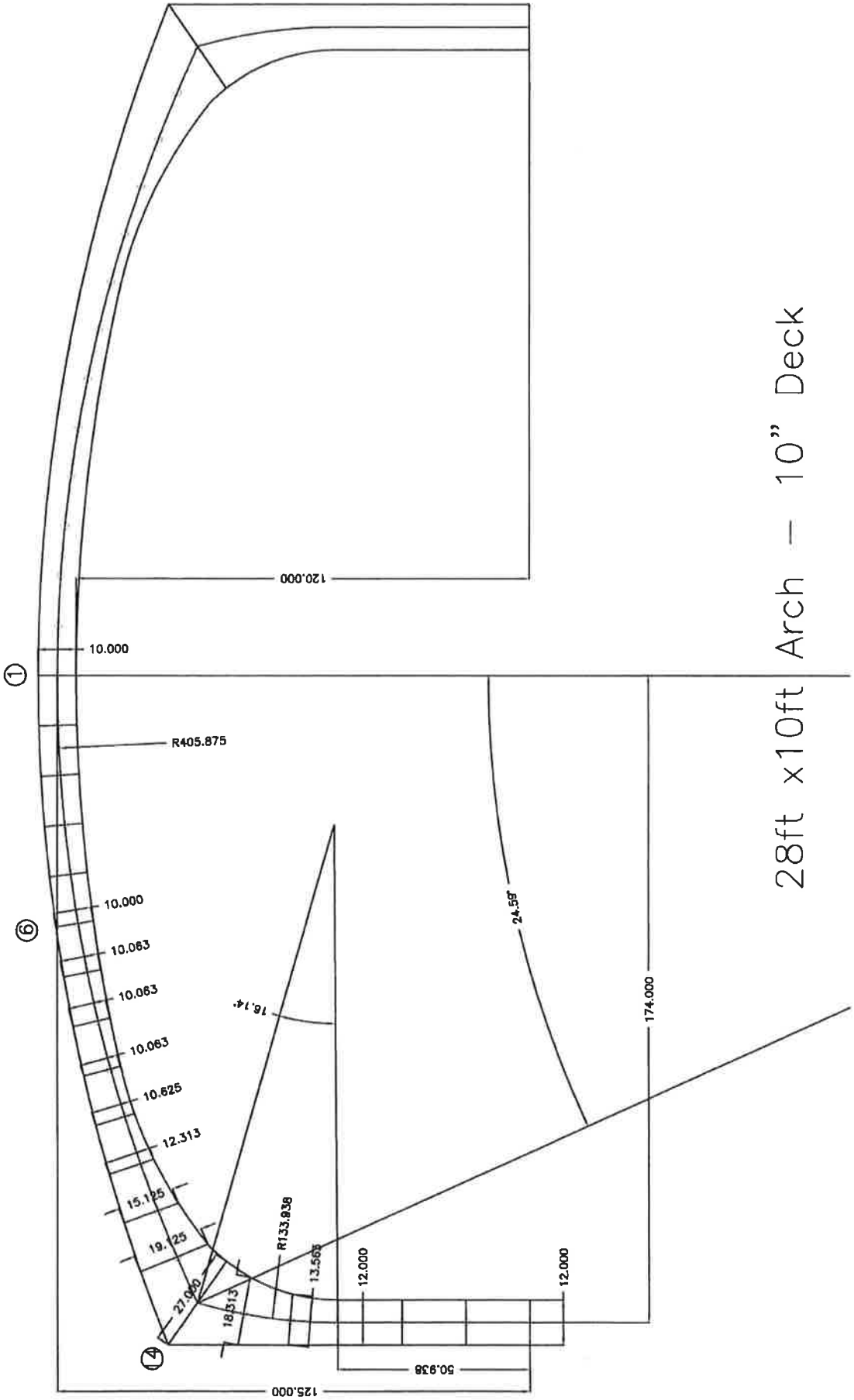
LOAD STEP 5-8 - EV : $1.3 \times 1.05 = 1.365$

LOAD STEP 9 - FWS : 1.5

LOAD STEP : 10-13 - LL : 1.75 INVENTORY RATING
1.35 OPERATING RATING

2014.059.004 Rochester VT 28x10

4



2014.059.004 Rochester VT 28x10

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

5

JOB	2014.059.004		
DESCIPTION	28'x10' Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	3/13/2014
CHECKED BY	SLV	DATE	3/20/14

Beam Information

Point from Crown	Thickness(in)	Beam Thickness(in)	Beam No.	Reinforcing Area (in^2/ft)		Reinforcing Area (in^2/in)	
				inside	outside	inside	outside
1	10			2.37	0.9	0.198	0.075
2	10	10	19	2.37	0.9	0.198	0.075
3	10	10	18	2.37	0.9	0.198	0.075
4	10	10	17	2.37	0.9	0.198	0.075
5	10	10	16	2.37	0.9	0.198	0.075
6	10	10	15	2.37	0.9	0.198	0.075
7	10.063	10.03	14	2.37	0.9	0.198	0.075
8	10.063	10.06	13	2.37	0.9	0.198	0.075
9	10.063	10.06	12	1.32	1.8	0.110	0.150
10	10.625	10.34	11	1.32	1.8	0.110	0.150
11	12.313	11.47	10	1.32	1.8	0.110	0.150
12	15.125	13.72	9	1.32	1.8	0.110	0.150
13	19.125	17.13	8	1.32	1.8	0.110	0.150
14	27	23.06	7	1.32	1.8	0.110	0.150
15	18.313	22.66	6	1.32	1.8	0.110	0.150
16	13.563	15.94	5	1.32	1.8	0.110	0.150
17	12	12.78	4	1.32	1.8	0.110	0.150
18	12	12	3	0.6	1.8	0.050	0.150
19	12	12	2	0.6	1.8	0.050	0.150
20	12	12	1	0.6	1.8	0.050	0.150

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCIPTION	28x10 Arch Load Rating		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/24/2014
CHECKED BY		DATE	

live load for <2' earth cover

span	28 ft	MPF	1.2
earth cover over structure	0 ft.	impact = 33*(1-0.125*earth cover) =	33 %
section width	5.96 ft	# of steps to divide load over in Cande =	4
		Skew Angle = 56 degrees	

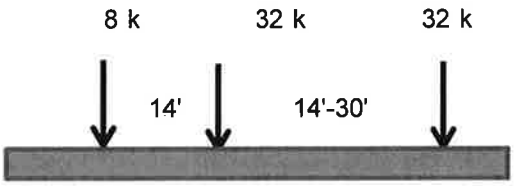
axle distribution width = 96+1.44*span = 11.36 feet

adjusted axle distribution width due to skew = 5.96 feet

axle load to input into Cande = axle weight*impact*MPF/distribution width/12" per ft/# of load steps

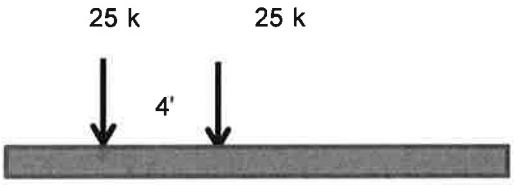
LOAD RATING VEHICLES

HL-93
72 kips
0.64 K/L.F. LANE LOAD



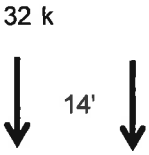
axle load to put into Cande
8 k = 44.63 lb/inch/step
32 k = 178.5 lb/inch/step

HL-93 TANDEM
50 KIPS (25 TONS)
0.64 K/L.F. LANE LOAD



axle load to put into Cande
25 k = 139.5 lb/inch/step
25 k = 139.5 lb/inch/step

H20 VEHICLE
20 TONS TOTAL



axle load to put into Cande
32 k = 178.5 lb/inch/step
8 k = 44.63 lb/inch/step

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCIPTION	28x10 Arch Load Rating		
SHEET NO.		OF	SCALE
CALCULATED BY	YL	DATE	11/24/2014
CHECKED BY		DATE	

live load for <2' earth cover

span	28 ft	MPF	1
earth cover over structure	0 ft.	impact = 33*(1-0.125*earth cover) =	33 %
section width	5.96 ft	# of steps to divide load over in Cande =	4
		Skew Angle = 56 degrees	

axle distribution width = 96+1.44*span = 11.36 feet

adjusted axle distribution width due to skew = 5.96 feet

axle load to input into Cande = axle weight*impact*MPF/distribution width/12" per ft/# of load steps

LOAD RATING VEHICLES

3S2 VEHICLE
36 TONS TOTAL

8 k, 16 k, 16 k, 16 k, 16 k
4', 22', 4', 11'

axle load to put into Cande
8 k = 37.19 lb/inch/step
16 k = 74.38 lb/inch/step

6 AXLE TRAILER
66 TONS TOTAL

12k, 24k, 24k, 24k, 24k, 24k
11', 4.67', 31', 4', 4'

axle load to put into Cande
12k = 55.79 lb/inch/step
24k = 111.6 lb/inch/step

3 AXLE STRAIGHT
30 TONS TOTAL

12k, 24k, 24k
15', 4'

axle load to put into Cande
12k = 55.79 lb/inch/step
24k = 111.6 lb/inch/step

4 AXLE STRAIGHT
34.5 TONS TOTAL

12k, 19k, 19k, 19k
15', 4', 4'

axle load to put into Cande
12k = 55.79 lb/inch/step
19k = 88.33 lb/inch/step

5 AXLE SEMI
38 TONS TOTAL

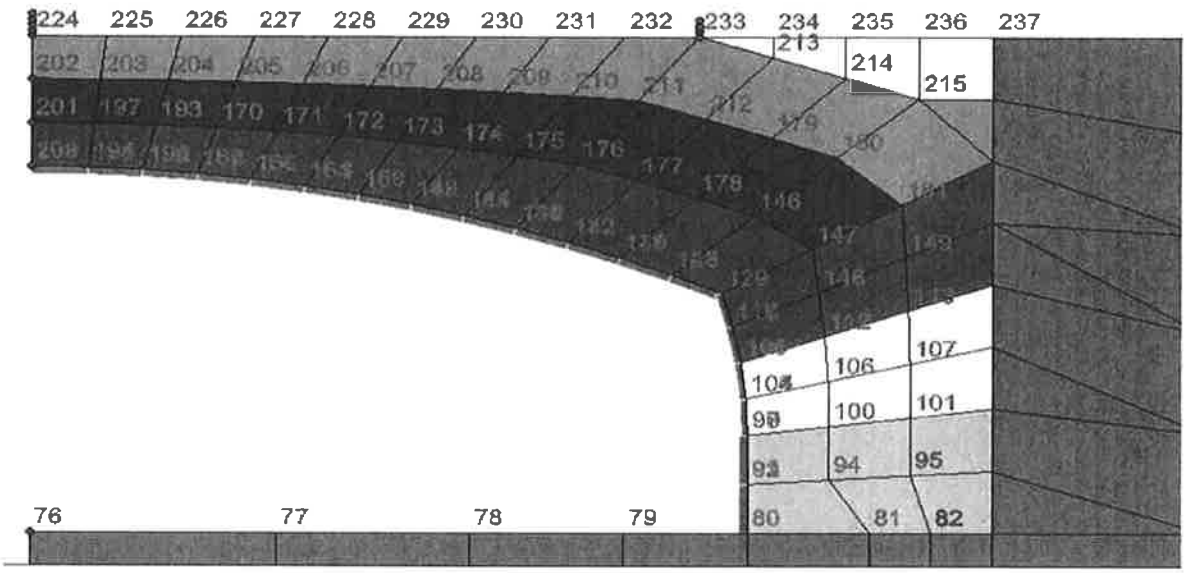
8k, 17k, 17k, 17k, 17k
11', 4', 16', 4'

axle load to put into Cande
8k = 37.19 lb/inch/step
17k = 79.03 lb/inch/step

2014.059.004 Rochester VT 28x10

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		8
DESCIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	3/17/2014
CHECKED BY	SLV	DATE	3/20/14



Lane load or additional dead load to input into CANDE

earth cover over structure	2 ft.	additional dead load (FWS)	0.035 ksf
span	28 ft	lane load	0.064 ksf

apply lane load as point load at top nodes

Node	coordinate	tributary width	unfactored dead load / node	unfactored lane load / node	
224	0 in.	1.5 ft.	2.188 lbs	4.8 lbs	<=== Cande doubles
225	18 in.	1.5 ft.	4.375 lbs	9.6 lbs	center load, so this is
226	36 in.	1.5 ft.	4.375 lbs	9.6 lbs	1/2 regular trib load
227	54 in.	1.5 ft.	4.375 lbs	9.6 lbs	
228	72 in.	1.5 ft.	4.375 lbs	9.6 lbs	
229	90 in.	1.5 ft.	4.375 lbs	9.6 lbs	
230	108 in.	1.5 ft.	4.375 lbs	9.6 lbs	
231	126 in.	1.5 ft.	4.375 lbs	9.6 lbs	
232	144 in.	1.5 ft.	4.375 lbs	9.6 lbs	
233	162 in.	1.5 ft.	4.375 lbs	9.6 lbs	
234	180 in.	1.5 ft.	4.375 lbs	9.6 lbs	live load from here out becomes
235	198 in.	1.5 ft.	4.375 lbs	9.6 lbs	beneficial and is neglected.
236	216 in.	1.5 ft.	4.375 lbs	9.6 lbs	dead load is applied because
237	234 in.				it is a perminant load

2014.059.004 Rochester VT 28x10

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		9
DESCIPTION	28x10 Arch		
SHEET NO	OF	SCALE	
CALCULATED BY	YL	DATE	3/13/2014
CHECKED BY	SLV	DATE	3/20/14

application point of live load HL-93 AND H20

span 28 ft

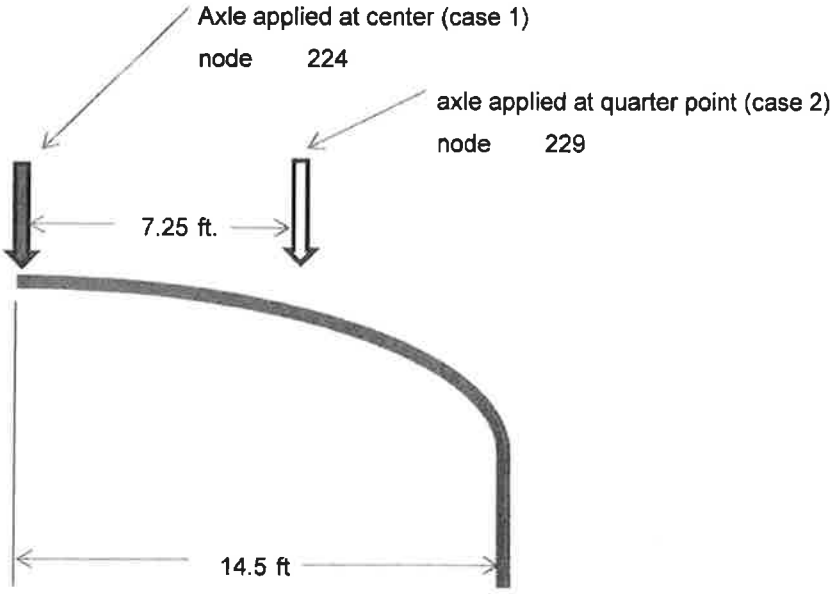
leg thickness 12 inches

case 1

axle applied to centerline

case 2

axle applied to quarter point only

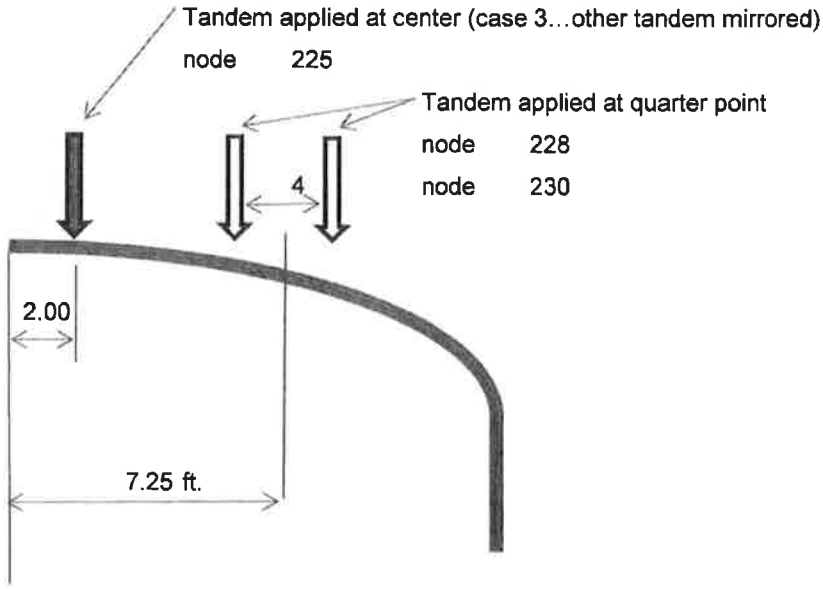


case 3

tandem applied at centerline

case 4

tandem applied at quarter point



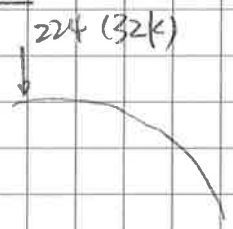
DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28X10 ARCH LOAD RATING		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/24/2014
CHECKED BY		DATE	

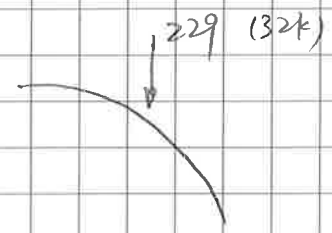
AN ISO 9001:2008 CERTIFIED COMPANY

LIVE LOAD POSITIONS

H20 =

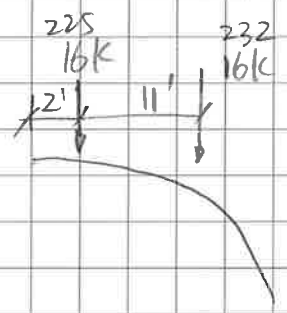


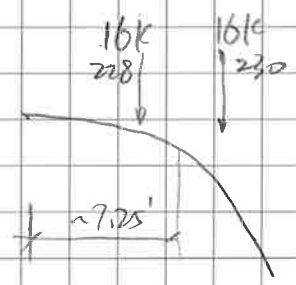
CASE 1



CASE 2

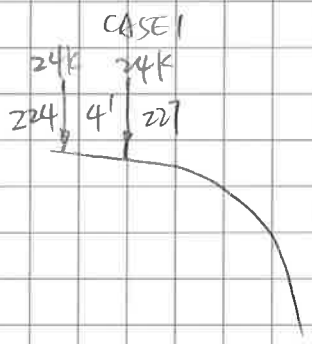
3S2 =



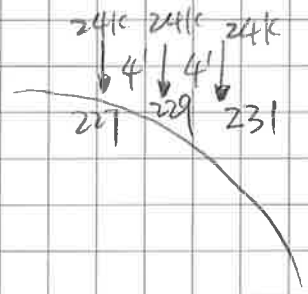


6 AXLE =

CASE 1

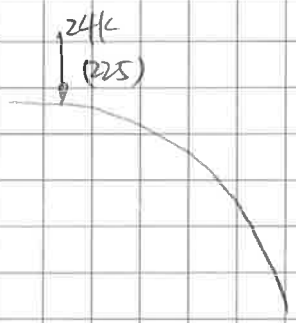


CASE 2



3 AXLE =

CASE 1



CASE 2

CASE 1

CASE 2

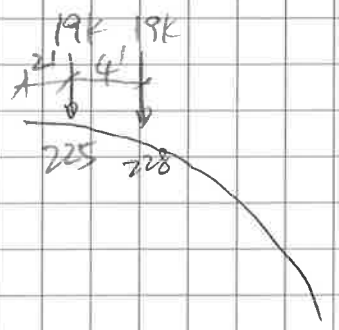
DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28X10 ARCH LOAD RATING		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/24/2014
CHECKED BY		DATE	

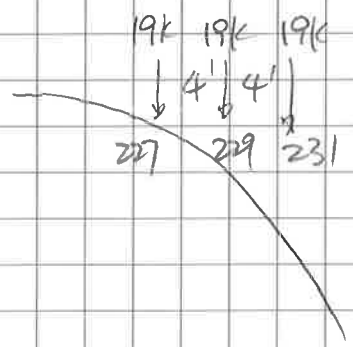
AN ISO 9001:2008 CERTIFIED COMPANY

LIVE LOAD POSITIONS (CON'T)

4 AXLE

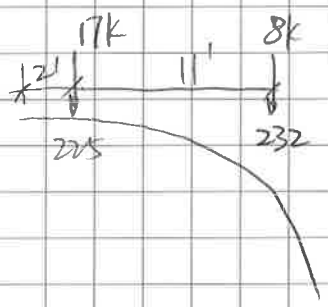


CASE 1

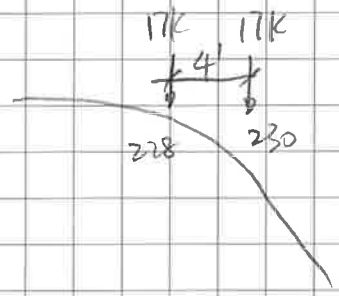


CASE 2

5 AXLE SEMI:



CASE 1



CASE 2

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 1

Technical Data & Load Factors

Culvert Span (S) =	28.00 ft.		
Crown Radius (Rad) =	33.82 ft.		
Bar Cover			
Outside Face (Cov_{out}) =	2.00 in		
Inside Face (Cov_{in}) =	1.50 in		
Design Section Length (b) =	12 in		
Compressive Strength (f_c) =	6.5 ksi		
Yield Strength (f_y) =	60 ksi		
Stirrup Yield Strength (f_{ystir}) =	60 ksi		
Circumferential Reinforcement Spa. (spa.) =	4.00 in		
Circumferential Reinforcement Provided (n) =	1	(n=1 for 1 layer, n=2 for multiple layers)	AASHTO
Reinforcement Type (Type) =	3	AASHTO Table	12.10.4.2.4d
1 - smooth wire or plain bar		12.10.4.4d-1	
2 - WWF (8" max spa. Smooth)			
3 - WWF (deformed) or bar (deformed)			

Resistance Factors:

ϕf - Flexure =	1.00	AASHTO Table 12.5.5-1
ϕr - Radial Tension =	0.90	
ϕv - Diag Tension =	0.90	
Radial Tension Process (F_{rp}) =	1.00	AASHTO 12.10.4.2.3
Diag Tension Process (F_{vp}) =	1.00	

Load Factors:

	IR	OR	
LL Factor	1.75	1.35	
γ_pDC (component)	1.31		(1.25*1.05 = 1.3125)
γ_pEH (hor. At rest earth pressure)	0.86		(0.9/1.05 = 0.857)
γ_pEV	1.37		(1.3*1.05 = 1.365)

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.		OF	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Design Force Summary LRFR LOAD RATING -HL93 Case 1

	Factored DC+EV+EH			Max Factored Total Load			Max Factored LL			
Node Number	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Thk at node (in)
1	-7.35	148.20	0.00	-13.01	622.45	1.43	-5.66	474.25	1.43	10.000
2	-7.40	145.37	0.42	-14.88	577.13	5.32	-7.48	431.76	4.90	10.000
3	-7.47	136.94	0.84	-16.27	479.70	7.92	-8.80	342.76	7.08	10.000
4	-7.59	122.94	1.26	-16.97	364.94	8.56	-9.37	242.00	7.31	10.000
5	-7.78	103.28	1.68	-17.37	250.25	8.44	-9.60	146.96	6.76	10.000
6	-8.03	77.90	2.12	-17.85	138.65	8.47	-9.82	60.75	6.36	10.000
7	-8.35	46.57	2.57	-18.42	23.21	8.68	-10.07	-23.37	6.11	10.063
8	-8.71	8.90	3.07	-19.00	-94.03	8.87	-10.28	-102.93	5.81	10.063
9	-9.13	-35.60	3.61	-19.65	-214.55	9.17	-10.51	-178.95	5.57	10.063
10	-9.60	-87.80	4.24	-20.37	-339.86	9.61	-10.78	-252.06	5.37	10.625
11	-10.09	-149.20	4.99	-21.19	-471.92	10.17	-11.10	-322.73	5.18	12.313
12	-10.63	-221.57	5.88	-22.09	-612.48	10.87	-11.47	-390.91	4.99	15.125
13	-11.22	-306.83	6.94	-23.13	-763.34	11.78	-11.91	-456.52	4.84	19.125
14	-13.21	-407.64	1.78	-24.88	-928.28	0.95	-11.67	-520.64	-0.83	27.000
15	-15.00	-357.89	-4.27	-25.87	-797.50	-10.91	-10.87	-439.61	-6.64	18.313
16	-15.14	-300.25	-4.92	-25.41	-654.14	-11.76	-10.28	-353.89	-6.84	13.563
17	-15.27	-234.07	-5.19	-25.01	-501.80	-11.58	-9.74	-267.73	-6.38	12.000
18	-15.50	-147.08	-4.81	-24.70	-314.48	-10.27	-9.20	-167.40	-5.46	12.000
19	-15.78	-70.81	-4.33	-24.58	-153.17	-9.26	-8.80	-82.36	-4.93	12.000
20	-16.07	0.00	-4.01	-24.67	0.00	-8.78	-8.60	0.00	-4.77	12.000

Note: "-" thrust indicate compression

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 1

Node	Total Fac.	Factored DC+EH+EV			Factored LL			
Number	Nu (k/ft)	Nu_D (k/ft)	Mu_D (in-k/ft)	Vu_D (k/ft)	Nu_{LL} (k/ft)	$+Mu_{LL}$ (in-k/ft)	Vu_{LL} (k/ft)	Thick (in)
1	-13.01	-7.35	148.20	0.00	-5.66	474.25	1.43	10
2	-14.88	-7.40	145.37	0.42	-7.48	431.76	4.90	10
3	-16.27	-7.47	136.94	0.84	-8.80	342.76	7.08	10
4	-16.97	-7.59	122.94	1.26	-9.37	242.00	7.31	10
5	-17.37	-7.78	103.28	1.68	-9.60	146.96	6.76	10
6	-17.85	-8.03	77.90	2.12	-9.82	60.75	6.36	10
7	-18.42	-8.35	46.57	2.57	-10.07	-23.37	6.11	10.063
8	-19.00	-8.71	8.90	3.07	-10.28	-102.93	5.81	10.063
9	-19.65	-9.13	-35.60	3.61	-10.51	-178.95	5.57	10.063
10	-20.37	-9.60	-87.80	4.24	-10.78	-252.06	5.37	10.625
11	-21.19	-10.09	-149.20	4.99	-11.10	-322.73	5.18	12.313
12	-22.09	-10.63	-221.57	5.88	-11.47	-390.91	4.99	15.125
13	-23.13	-11.22	-306.83	6.94	-11.91	-456.52	4.84	19.125
14	-24.88	-13.21	-407.64	1.78	-11.67	-520.64	0.83	27
15	-25.87	-15.00	-357.89	4.27	-10.87	-439.61	6.64	18.313
16	-25.41	-15.14	-300.25	4.92	-10.28	-353.89	6.84	13.563
17	-25.01	-15.27	-234.07	5.19	-9.74	-267.73	6.38	12
18	-24.70	-15.50	-147.08	4.81	-9.20	-167.40	5.46	12
19	-24.58	-15.78	-70.81	4.33	-8.80	-82.36	4.93	12
20	-24.67	-16.07	0.00	4.01	-8.60	0.00	4.77	12

note all shear values normalized to positive

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Node Number	thk (in)	d (in)	As'in (prov'd) (in^2 / ft)	As'out (prov'd) (in^2 / ft)
1	10.0	8.13	2.38	0.90
2	10.0	8.13	2.38	0.90
3	10.0	8.13	2.38	0.90
4	10.0	8.13	2.38	0.90
5	10.0	8.13	2.38	0.90
6	10.0	8.13	2.38	0.90
7	10.1	8.19	2.38	0.90
8	10.1	7.69	2.38	0.90
9	10.1	7.69	1.32	1.80
10	10.6	8.25	1.32	1.80
11	12.3	9.94	1.32	1.80
12	15.1	12.75	1.32	1.80
13	19.1	16.75	1.32	1.80
14	27.0	24.63	1.32	1.80
15	18.3	15.94	1.32	1.80
16	13.6	11.19	1.32	1.80
17	12.0	9.63	1.32	1.80
18	12.0	9.63	0.60	1.80
19	12.0	9.63	0.60	1.80
20	12.0	9.63	0.60	1.80

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 1

Node Number	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Total Fac. Nu (k/ft)	Phi Mn (in-k/ft)
1	10.0	8.13	2.38	-13.01	1040.84
2	10.0	8.13	2.38	-14.88	1045.76
3	10.0	8.13	2.38	-16.27	1049.41
4	10.0	8.13	2.38	-16.97	1051.21
5	10.0	8.13	2.38	-17.37	1052.27
6	10.0	8.13	2.38	-17.85	1053.50
7	10.1	8.19	2.38	-18.42	1064.53
8	10.1	7.69	0.90	-19.00	470.56
9	10.1	7.69	1.80	-19.65	806.28
10	10.6	8.25	1.80	-20.37	874.95
11	12.3	9.94	1.80	-21.19	1077.88
12	15.1	12.75	1.80	-22.09	1416.44
13	19.1	16.75	1.80	-23.13	1900.50
14	27.0	24.63	1.80	-24.88	2862.20
15	18.3	15.94	1.80	-25.87	1823.02
16	13.6	11.19	1.80	-25.41	1246.42
17	12.0	9.63	1.80	-25.01	1056.15
18	12.0	9.63	1.80	-24.70	1054.91
19	12.0	9.63	1.80	-24.58	1054.42
20	12.0	9.63	1.80	-24.67	1054.77

AASHTO 12.10.4.2.4a

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 1

Node Number	thk (in)	d (in)	Phi Mn (in-k/ft)	Mu_D (in-k/ft)	$+Mu_{LL}$ (in-k/ft)	Inventory Rating	Operating Rating
1	10.0	8.13	1040.84	148.20	474.25	1.88	2.44
2	10.0	8.13	1045.76	145.37	431.76	2.09	2.70
3	10.0	8.13	1049.41	136.94	342.76	2.66	3.45
4	10.0	8.13	1051.21	122.94	242.00	3.84	4.97
5	10.0	8.13	1052.27	103.28	146.96	6.46	8.37
6	10.0	8.13	1053.50	77.90	60.75	16.06	20.82
7	10.1	8.19	1064.53	46.57	-23.37	47.55	61.64
8	10.1	7.69	470.56	8.90	-102.93	4.66	6.04
9	10.1	7.69	806.28	-35.60	-178.95	4.31	5.58
10	10.6	8.25	874.95	-87.80	-252.06	3.12	4.05
11	12.3	9.94	1077.88	-149.20	-322.73	2.88	3.73
12	15.1	12.75	1416.44	-221.57	-390.91	3.06	3.96
13	19.1	16.75	1900.50	-306.83	-456.52	3.49	4.53
14	27.0	24.63	2862.20	-407.64	-520.64	4.71	6.11
15	18.3	15.94	1823.02	-357.89	-439.61	3.33	4.32
16	13.6	11.19	1246.42	-300.25	-353.89	2.67	3.47
17	12.0	9.63	1056.15	-234.07	-267.73	3.07	3.98
18	12.0	9.63	1054.91	-147.08	-167.40	5.42	7.03
19	12.0	9.63	1054.42	-70.81	-82.36	11.94	15.48
20	12.0	9.63	1054.77	0.00	0.00	N/A	N/A
					Controlling	**1.88**	**2.44**

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA ENGINEERS
184 Court Street
BINGHAMTON, NEW YORK 13901
(607) 231-6600 Fax 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 1

Elmt Nmbr	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Vtotal (kip/ft)	Vdl only (kip/ft)	Vll only (kip/ft)	ϕVn (kip/ft)	1.75 INV	1.35 OPR
1	10.0	8.125	2.38	1.43	0.00	1.43	19.08	13.35	17.31
2	10.0	8.125	2.38	5.32	0.42	4.90	19.22	3.832	4.968
3	10.0	8.125	2.38	7.92	0.84	7.08	19.32	2.61	3.384
4	10.0	8.125	2.38	8.56	1.26	7.31	19.37	2.48	3.214
5	10.0	8.125	2.38	8.44	1.68	6.76	19.40	2.62	3.397
6	10.0	8.125	2.38	8.47	2.12	6.36	27.95	4.064	5.269
7	10.1	8.188	2.38	8.68	2.57	6.11	31.57	4.747	6.154
8	10.1	7.688	0.90	8.87	3.07	5.81	24.82	3.747	4.858
9	10.1	7.688	1.80	9.17	3.61	5.57	18.61	2.696	3.494
10	10.6	8.250	1.80	9.61	4.24	5.37	17.68	2.505	3.247
11	12.3	9.938	1.80	10.17	4.99	5.18	18.75	2.656	3.443
12	15.1	12.750	1.80	10.87	5.88	4.99	20.77	2.981	3.865
13	19.1	16.750	1.80	11.78	6.94	4.84	23.91	3.506	4.544
14	27.0	24.625	1.80	0.95	1.78	0.83	30.67	34.68	44.95
15	18.3	15.938	1.80	10.91	4.27	6.64	23.40	2.883	3.737
16	13.6	11.188	1.80	11.76	4.92	6.84	19.84	2.181	2.828
17	12.0	9.625	1.80	11.58	5.19	6.38	18.78	2.129	2.76
18	12.0	9.625	1.80	10.27	4.81	5.46	19.26	2.648	3.432
19	12.0	9.625	1.80	9.26	4.33	4.93	31.37	5.486	7.111
20	12.0	9.625	1.80	8.78	4.01	4.77	39.15	7.363	9.545
							controling:	**2.129**	**2.76**

$$F_d = 0.8 + \frac{1.6}{d} \le 1.3$$

$$F_n = 1 + \frac{N_u}{24 * thk}$$

$$\rho = \frac{A_s}{\phi bd} \le 0.02$$

$$\phi V_n = \phi 0.0316 b d F_{vp} \sqrt{f'c}\left(1.1 + 63\rho\right)\left(\frac{F_d F_n}{F_c}\right)$$

$$F_c = 1 \pm \left(\frac{d}{2 * rad}\right)$$

Shear Resistance Without Stirrups **AASHTO 12.10.4.2.5**

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 2

Technical Data & Load Factors

Culvert Span (S) =	28.00 ft.		
Crown Radius (Rad) =	33.82 ft.		
Bar Cover			
Outside Face (Cov_{out}) =	2.00 in		
Inside Face (Cov_{in}) =	1.50 in		
Design Section Length (b) =	12 in		
Compressive Strength (f_c) =	6.5 ksi		
Yield Strength (f_y) =	60 ksi		
Stirrup Yield Strength (f_{ystir}) =	60 ksi		
Circumferential Reinforcement Spa. (spa.) =	4.00 in		
Circumferential Reinforcement Provided (n) =	1	(n=1 for 1 layer, n=2 for multiple layers)	AASHTO
Reinforcement Type (Type) =	3	AASHTO Table	12.10.4.2.4d
1 - smooth wire or plain bar		12.10.4.4d-1	
2 - WWF (8" max spa. Smooth)			
3 - WWF (deformed) or bar (deformed)			

Resistance Factors:

ϕf - Flexure =	1.00	AASHTO Table 12.5.5-1
ϕr - Radial Tension =	0.90	AASHTO Table 12.5.5-1
ϕv - Diag Tension =	0.90	AASHTO Table 12.5.5-1
Radial Tension Process (F_{rp}) =	1.00	AASHTO 12.10.4.2.3
Diag Tension Process (F_{vp}) =	1.00	AASHTO 12.10.4.2.3

Load Factors:

	IR	OR	
LL Factor	1.75	1.35	
γ_pDC (component)	1.31		(1.25*1.05 = 1.3125)
γ_pEH (hor. At rest earth pressure)	0.86		(0.9/1.05 = 0.857)
γ_pEV	1.37		(1.3*1.05 = 1.365)

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.		OF	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Design Force Summary LRFR LOAD RATING -HL93 Case 2

	Factored DC+EV+EH			Max Factored Total Load			Max Factored LL			
Node Number	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Thk at node (in)
1	-7.35	148.20	0.00	-20.08	310.76	0.01	-12.73	162.56	0.01	10.000
2	-7.40	145.37	0.42	-20.14	309.74	0.14	-12.74	164.38	-0.28	10.000
3	-7.47	136.94	0.84	-20.23	307.03	0.22	-12.76	170.09	-0.62	10.000
4	-7.59	122.94	1.26	-20.30	303.80	0.25	-12.70	180.86	-1.01	10.000
5	-7.78	103.28	1.68	-20.05	300.35	0.72	-12.27	197.06	-0.96	10.000
6	-8.03	77.90	2.12	-19.36	284.54	2.55	-11.34	206.64	0.44	10.000
7	-8.35	46.57	2.57	-19.07	231.95	5.68	-10.73	185.37	3.11	10.063
8	-8.71	8.90	3.07	-20.24	132.25	9.33	-11.52	123.35	6.26	10.063
9	-9.13	-35.60	3.61	-22.51	-18.08	13.42	-13.37	17.52	9.81	10.063
10	-9.60	-87.80	4.24	-24.21	-227.29	15.75	-14.61	-139.49	11.51	10.625
11	-10.09	-149.20	4.99	-25.20	-440.09	16.13	-15.11	-290.89	11.14	12.313
12	-10.63	-221.57	5.88	-26.26	-659.52	16.60	-15.63	-437.95	10.72	15.125
13	-11.22	-306.83	6.94	-27.40	-884.98	17.18	-16.18	-578.15	10.23	19.125
14	-13.21	-407.64	1.78	-30.53	-1119.77	3.10	-17.32	-712.13	1.32	27.000
15	-15.00	-357.89	-4.27	-32.85	-977.46	-12.31	-17.85	-619.57	-8.04	18.313
16	-15.14	-300.25	-4.92	-32.36	-810.36	-14.00	-17.22	-510.11	-9.08	13.563
17	-15.27	-234.07	-5.19	-31.91	-625.38	-14.21	-16.64	-391.31	-9.02	12.000
18	-15.50	-147.08	-4.81	-31.59	-392.70	-12.77	-16.08	-245.62	-7.97	12.000
19	-15.78	-70.81	-4.33	-31.45	-191.56	-11.56	-15.67	-120.75	-7.23	12.000
20	-16.07	0.00	-4.01	-31.50	0.00	-11.00	-15.43	0.00	-6.99	12.000

Note: "-" thrust indicate compression

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 2

Node	Total Fac.	Factored DC+EH+EV			Factored LL			
Number	Nu (k/ft)	Nu_D (k/ft)	Mu_D (in-k/ft)	Vu_D (k/ft)	Nu_{LL} (k/ft)	$+Mu_{LL}$ (in-k/ft)	Vu_{LL} (k/ft)	Thick (in)
1	-20.08	-7.35	148.20	0.00	-12.73	162.56	0.01	10
2	-20.14	-7.40	145.37	0.42	-12.74	164.38	0.28	10
3	-20.23	-7.47	136.94	0.84	-12.76	170.09	0.62	10
4	-20.30	-7.59	122.94	1.26	-12.70	180.86	1.01	10
5	-20.05	-7.78	103.28	1.68	-12.27	197.06	0.96	10
6	-19.36	-8.03	77.90	2.12	-11.34	206.64	0.44	10
7	-19.07	-8.35	46.57	2.57	-10.73	185.37	3.11	10.063
8	-20.24	-8.71	8.90	3.07	-11.52	123.35	6.26	10.063
9	-22.51	-9.13	-35.60	3.61	-13.37	17.52	9.81	10.063
10	-24.21	-9.60	-87.80	4.24	-14.61	-139.49	11.51	10.625
11	-25.20	-10.09	-149.20	4.99	-15.11	-290.89	11.14	12.313
12	-26.26	-10.63	-221.57	5.88	-15.63	-437.95	10.72	15.125
13	-27.40	-11.22	-306.83	6.94	-16.18	-578.15	10.23	19.125
14	-30.53	-13.21	-407.64	1.78	-17.32	-712.13	1.32	27
15	-32.85	-15.00	-357.89	4.27	-17.85	-619.57	8.04	18.313
16	-32.36	-15.14	-300.25	4.92	-17.22	-510.11	9.08	13.563
17	-31.91	-15.27	-234.07	5.19	-16.64	-391.31	9.02	12
18	-31.59	-15.50	-147.08	4.81	-16.08	-245.62	7.97	12
19	-31.45	-15.78	-70.81	4.33	-15.67	-120.75	7.23	12
20	-31.50	-16.07	0.00	4.01	-15.43	0.00	6.99	12

note all shear values normalized to positive

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Node Number	thk (in)	d (in)	As'in (prov'd) (in^2 / ft)	As'out (prov'd) (in^2 / ft)
1	10.0	8.13	2.38	0.90
2	10.0	8.13	2.38	0.90
3	10.0	8.13	2.38	0.90
4	10.0	8.13	2.38	0.90
5	10.0	8.13	2.38	0.90
6	10.0	8.13	2.38	0.90
7	10.1	8.19	2.38	0.90
8	10.1	8.19	2.38	0.90
9	10.1	7.69	1.32	1.80
10	10.6	8.25	1.32	1.80
11	12.3	9.94	1.32	1.80
12	15.1	12.75	1.32	1.80
13	19.1	16.75	1.32	1.80
14	27.0	24.63	1.32	1.80
15	18.3	15.94	1.32	1.80
16	13.6	11.19	1.32	1.80
17	12.0	9.63	1.32	1.80
18	12.0	9.63	0.60	1.80
19	12.0	9.63	0.60	1.80
20	12.0	9.63	0.60	1.80

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 2

Node Number	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Total Fac. Nu (k/ft)	Phi Mn (in-k/ft)
1	10.0	8.13	2.38	-20.08	1059.22
2	10.0	8.13	2.38	-20.14	1059.38
3	10.0	8.13	2.38	-20.23	1059.60
4	10.0	8.13	2.38	-20.30	1059.77
5	10.0	8.13	2.38	-20.05	1059.13
6	10.0	8.13	2.38	-19.36	1057.39
7	10.1	8.19	2.38	-19.07	1066.22
8	10.1	8.19	2.38	-20.24	1069.24
9	10.1	7.69	1.80	-22.51	815.10
10	10.6	8.25	1.80	-24.21	887.79
11	12.3	9.94	1.80	-25.20	1094.64
12	15.1	12.75	1.80	-26.26	1439.63
13	19.1	16.75	1.80	-27.40	1932.75
14	27.0	24.63	1.80	-30.53	2926.93
15	18.3	15.94	1.80	-32.85	1872.49
16	13.6	11.19	1.80	-32.36	1279.16
17	12.0	9.63	1.80	-31.91	1083.33
18	12.0	9.63	1.80	-31.59	1082.08
19	12.0	9.63	1.80	-31.45	1081.54
20	12.0	9.63	1.80	-31.50	1081.74

AASHTO 12.10.4.2.4a

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 2

Node Number	thk (in)	d (in)	Phi Mn (in-k/ft)	Mu_D (in-k/ft)	$+Mu_{LL}$ (in-k/ft)	Inventory Rating	Operating Rating
1	10.0	8.13	1059.22	148.20	162.56	5.60	7.26
2	10.0	8.13	1059.38	145.37	164.38	5.56	7.21
3	10.0	8.13	1059.60	136.94	170.09	5.42	7.03
4	10.0	8.13	1059.77	122.94	180.86	5.18	6.71
5	10.0	8.13	1059.13	103.28	197.06	4.85	6.29
6	10.0	8.13	1057.39	77.90	206.64	4.74	6.14
7	10.1	8.19	1066.22	46.57	185.37	5.50	7.13
8	10.1	8.19	1069.24	8.90	123.35	8.60	11.14
9	10.1	7.69	815.10	-35.60	17.52	48.56	62.95
10	10.6	8.25	887.79	-87.80	-139.49	5.74	7.43
11	12.3	9.94	1094.64	-149.20	-290.89	3.25	4.21
12	15.1	12.75	1439.63	-221.57	-437.95	2.78	3.61
13	19.1	16.75	1932.75	-306.83	-578.15	2.81	3.65
14	27.0	24.63	2926.93	-407.64	-712.13	3.54	4.59
15	18.3	15.94	1872.49	-357.89	-619.57	2.44	3.17
16	13.6	11.19	1279.16	-300.25	-510.11	1.92	2.49
17	12.0	9.63	1083.33	-234.07	-391.31	2.17	2.81
18	12.0	9.63	1082.08	-147.08	-245.62	3.81	4.93
19	12.0	9.63	1081.54	-70.81	-120.75	8.37	10.85
20	12.0	9.63	1081.74	0.00	0.00	N/A	N/A
					Controlling	**1.92**	**2.49**

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA ENGINEERS
184 Court Street
BINGHAMTON, NEW YORK 13901
(607) 231-6600 Fax 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 2

Elmt Nmbr	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Vtotal (kip/ft)	Vdl only (kip/ft)	Vll only (kip/ft)	ϕVn (kip/ft)	1.75 INV	1.35 OPR
1	10.0	8.125	2.38	0.01	0.00	0.01	19.61	1702	2206
2	10.0	8.125	2.38	0.14	0.42	0.28	19.61	68.41	88.68
3	10.0	8.125	2.38	0.22	0.84	0.62	19.62	30.5	39.54
4	10.0	8.125	2.38	0.25	1.26	1.01	19.62	18.24	23.65
5	10.0	8.125	2.38	0.72	1.68	0.96	19.61	18.64	24.16
6	10.0	8.125	2.38	2.55	2.12	0.44	19.55	39.96	51.79
7	10.1	8.188	2.38	5.68	2.57	3.11	19.55	5.462	7.08
8	10.1	8.188	2.38	9.33	3.07	6.26	31.56	4.55	5.898
9	10.1	7.688	1.80	13.42	3.61	9.81	29.86	2.676	3.469
10	10.6	8.250	1.80	15.75	4.24	11.51	28.29	2.09	2.709
11	12.3	9.938	1.80	16.13	4.99	11.14	21.28	1.462	1.896
12	15.1	12.750	1.80	16.60	5.88	10.72	21.10	1.42	1.84
13	19.1	16.750	1.80	17.18	6.94	10.23	24.30	1.696	2.199
14	27.0	24.625	1.80	3.10	1.78	1.32	30.93	22.16	28.73
15	18.3	15.938	1.80	12.31	4.27	8.04	23.75	2.423	3.141
16	13.6	11.188	1.80	14.00	4.92	9.08	20.23	1.686	2.185
17	12.0	9.625	1.80	14.21	5.19	9.02	19.20	1.553	2.013
18	12.0	9.625	1.80	12.77	4.81	7.97	19.67	1.866	2.418
19	12.0	9.625	1.80	11.56	4.33	7.23	32.14	3.845	4.984
20	12.0	9.625	1.80	11.00	4.01	6.99	37.44	4.782	6.199
							controling:	**1.42**	**1.84**

$$F_d = 0.8 + \frac{1.6}{d} \le 1.3$$

$$F_n = 1 + \frac{N_u}{24 * thk}$$

$$\rho = \frac{A_s}{\phi bd} \le 0.02$$

$$\phi V_n = \phi 0.0316 b d F_{vp} \sqrt{f'c}\left(1.1 + 63\rho\right)\left(\frac{F_d F_n}{F_c}\right)$$

$$F_c = 1 \pm \left(\frac{d}{2 * rad}\right)$$

Shear Resistance Without Stirrups **AASHTO 12.10.4.2.5**

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 3

Technical Data & Load Factors

Culvert Span (S) =	28.00 ft.		
Crown Radius (Rad) =	33.82 ft.		
Bar Cover			
Outside Face (Cov_{out}) =	2.00 in		
Inside Face (Cov_{in}) =	1.50 in		
Design Section Length (b) =	12 in		
Compressive Strength (f_c) =	6.5 ksi		
Yield Strength (f_y) =	60 ksi		
Stirrup Yield Strength (f_{ystir}) =	60 ksi		
Circumferential Reinforcement Spa. (spa.) =	4.00 in		
Circumferential Reinforcement Provided (n) =	1	(n=1 for 1 layer, n=2 for multiple layers)	AASHTO
Reinforcement Type (Type) =	3	AASHTO Table	12.10.4.2.4d

1 - smooth wire or plain bar — 12.10.4.4d-1
2 - WWF (8" max spa. Smooth)
3 - WWF (deformed) or bar (deformed)

Resistance Factors:

ϕf - Flexure =	1.00	AASHTO Table 12.5.5-1
ϕr - Radial Tension =	0.90	
ϕv - Diag Tension =	0.90	
Radial Tension Process (F_{rp}) =	1.00	AASHTO 12.10.4.2.3
Diag Tension Process (F_{vp}) =	1.00	

Load Factors:

	IR	OR	
LL Factor	1.75	1.35	
$\gamma_p DC$ (component)	1.31		(1.25*1.05 = 1.3125)
$\gamma_p EH$ (hor. At rest earth pressure)	0.86		(0.9/1.05 = 0.857)
$\gamma_p EV$	1.37		(1.3*1.05 = 1.365)

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.		OF	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Design Force Summary LRFR LOAD RATING -HL93 Case 3

	Factored DC+EV+EH			Max Factored Total Load			Max Factored LL			
Node Number	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Thk at node (in)
1	-7.35	148.20	0.00	-19.06	770.72	-0.50	-11.71	622.52	-0.50	10.000
2	-7.40	145.37	0.42	-19.22	742.27	4.74	-11.82	596.90	4.32	10.000
3	-7.47	136.94	0.84	-20.17	643.79	8.92	-12.70	506.84	8.08	10.000
4	-7.59	122.94	1.26	-21.68	503.35	11.30	-14.09	380.41	10.05	10.000
5	-7.78	103.28	1.68	-22.69	340.86	12.26	-14.92	237.58	10.58	10.000
6	-8.03	77.90	2.12	-23.29	174.83	12.10	-15.26	96.93	9.98	10.000
7	-8.35	46.57	2.57	-23.85	16.67	11.82	-15.50	-29.91	9.25	10.063
8	-8.71	8.90	3.07	-24.52	-141.92	11.82	-15.81	-150.82	8.75	10.063
9	-9.13	-35.60	3.61	-25.25	-300.01	11.91	-16.12	-264.42	8.30	10.063
10	-9.60	-87.80	4.24	-26.09	-460.97	12.20	-16.49	-373.17	7.96	10.625
11	-10.09	-149.20	4.99	-27.01	-627.04	12.66	-16.92	-477.84	7.66	12.313
12	-10.63	-221.57	5.88	-28.04	-800.14	13.26	-17.41	-578.57	7.38	15.125
13	-11.22	-306.83	6.94	-29.12	-982.31	14.08	-17.90	-675.48	7.14	19.125
14	-13.21	-407.64	1.78	-30.48	-1177.56	0.54	-17.26	-769.92	-1.25	27.000
15	-15.00	-357.89	-4.27	-30.95	-1008.01	-14.04	-15.95	-650.12	-9.77	18.313
16	-15.14	-300.25	-4.92	-30.19	-824.76	-14.93	-15.05	-524.51	-10.01	13.563
17	-15.27	-234.07	-5.19	-29.50	-632.62	-14.59	-14.22	-398.54	-9.40	12.000
18	-15.50	-147.08	-4.81	-28.98	-396.52	-12.94	-13.47	-249.43	-8.13	12.000
19	-15.78	-70.81	-4.33	-28.75	-193.15	-11.68	-12.97	-122.35	-7.34	12.000
20	-16.07	0.00	-4.01	-28.79	0.00	-11.08	-12.71	0.00	-7.07	12.000

Note: "-" thrust indicate compression

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 3

Node	Total Fac.	Factored DC+EH+EV			Factored LL			
Number	Nu (k/ft)	Nu_D (k/ft)	Mu_D (in-k/ft)	Vu_D (k/ft)	Nu_{LL} (k/ft)	$+Mu_{LL}$ (in-k/ft)	Vu_{LL} (k/ft)	Thick (in)
1	-19.06	-7.35	148.20	0.00	-11.71	622.52	0.50	10
2	-19.22	-7.40	145.37	0.42	-11.82	596.90	4.32	10
3	-20.17	-7.47	136.94	0.84	-12.70	506.84	8.08	10
4	-21.68	-7.59	122.94	1.26	-14.09	380.41	10.05	10
5	-22.69	-7.78	103.28	1.68	-14.92	237.58	10.58	10
6	-23.29	-8.03	77.90	2.12	-15.26	96.93	9.98	10
7	-23.85	-8.35	46.57	2.57	-15.50	-29.91	9.25	10.063
8	-24.52	-8.71	8.90	3.07	-15.81	-150.82	8.75	10.063
9	-25.25	-9.13	-35.60	3.61	-16.12	-264.42	8.30	10.063
10	-26.09	-9.60	-87.80	4.24	-16.49	-373.17	7.96	10.625
11	-27.01	-10.09	-149.20	4.99	-16.92	-477.84	7.66	12.313
12	-28.04	-10.63	-221.57	5.88	-17.41	-578.57	7.38	15.125
13	-29.12	-11.22	-306.83	6.94	-17.90	-675.48	7.14	19.125
14	-30.48	-13.21	-407.64	1.78	-17.26	-769.92	1.25	27
15	-30.95	-15.00	-357.89	4.27	-15.95	-650.12	9.77	18.313
16	-30.19	-15.14	-300.25	4.92	-15.05	-524.51	10.01	13.563
17	-29.50	-15.27	-234.07	5.19	-14.22	-398.54	9.40	12
18	-28.98	-15.50	-147.08	4.81	-13.47	-249.43	8.13	12
19	-28.75	-15.78	-70.81	4.33	-12.97	-122.35	7.34	12
20	-28.79	-16.07	0.00	4.01	-12.71	0.00	7.07	12

note all shear values normalized to positive

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Node Number	thk (in)	d (in)	As'in (prov'd) (in^2 / ft)	As'out (prov'd) (in^2 / ft)
1	10.0	8.13	2.38	0.90
2	10.0	8.13	2.38	0.90
3	10.0	8.13	2.38	0.90
4	10.0	8.13	2.38	0.90
5	10.0	8.13	2.38	0.90
6	10.0	8.13	2.38	0.90
7	10.1	8.19	2.38	0.90
8	10.1	7.69	2.38	0.90
9	10.1	7.69	1.32	1.80
10	10.6	8.25	1.32	1.80
11	12.3	9.94	1.32	1.80
12	15.1	12.75	1.32	1.80
13	19.1	16.75	1.32	1.80
14	27.0	24.63	1.32	1.80
15	18.3	15.94	1.32	1.80
16	13.6	11.19	1.32	1.80
17	12.0	9.63	1.32	1.80
18	12.0	9.63	0.60	1.80
19	12.0	9.63	0.60	1.80
20	12.0	9.63	0.60	1.80

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 3

Node Number	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Total Fac. Nu (k/ft)	Phi Mn (in-k/ft)
1	10.0	8.13	2.38	-19.06	1056.60
2	10.0	8.13	2.38	-19.22	1057.01
3	10.0	8.13	2.38	-20.17	1059.45
4	10.0	8.13	2.38	-21.68	1063.27
5	10.0	8.13	2.38	-22.69	1065.82
6	10.0	8.13	2.38	-23.29	1067.31
7	10.1	8.19	2.38	-23.85	1078.43
8	10.1	7.69	0.90	-24.52	492.03
9	10.1	7.69	1.80	-25.25	823.45
10	10.6	8.25	1.80	-26.09	894.00
11	12.3	9.94	1.80	-27.01	1102.14
12	15.1	12.75	1.80	-28.04	1449.47
13	19.1	16.75	1.80	-29.12	1945.64
14	27.0	24.63	1.80	-30.48	2926.32
15	18.3	15.94	1.80	-30.95	1859.08
16	13.6	11.19	1.80	-30.19	1269.01
17	12.0	9.63	1.80	-29.50	1073.90
18	12.0	9.63	1.80	-28.98	1071.86
19	12.0	9.63	1.80	-28.75	1070.96
20	12.0	9.63	1.80	-28.79	1071.11

AASHTO 12.10.4.2.4a

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 3

Node Number	thk (in)	d (in)	Phi Mn (in-k/ft)	Mu_D (in-k/ft)	$+Mu_{LL}$ (in-k/ft)	Inventory Rating	Operating Rating
1	10.0	8.13	1056.60	148.20	622.52	1.46	1.89
2	10.0	8.13	1057.01	145.37	596.90	1.53	1.98
3	10.0	8.13	1059.45	136.94	506.84	1.82	2.36
4	10.0	8.13	1063.27	122.94	380.41	2.47	3.20
5	10.0	8.13	1065.82	103.28	237.58	4.05	5.25
6	10.0	8.13	1067.31	77.90	96.93	10.21	13.23
7	10.1	8.19	1078.43	46.57	-29.91	37.62	48.76
8	10.1	7.69	492.03	8.90	-150.82	3.32	4.31
9	10.1	7.69	823.45	-35.60	-264.42	2.98	3.86
10	10.6	8.25	894.00	-87.80	-373.17	2.16	2.80
11	12.3	9.94	1102.14	-149.20	-477.84	1.99	2.59
12	15.1	12.75	1449.47	-221.57	-578.57	2.12	2.75
13	19.1	16.75	1945.64	-306.83	-675.48	2.43	3.15
14	27.0	24.63	2926.32	-407.64	-769.92	3.27	4.24
15	18.3	15.94	1859.08	-357.89	-650.12	2.31	2.99
16	13.6	11.19	1269.01	-300.25	-524.51	1.85	2.39
17	12.0	9.63	1073.90	-234.07	-398.54	2.11	2.73
18	12.0	9.63	1071.86	-147.08	-249.43	3.71	4.81
19	12.0	9.63	1070.96	-70.81	-122.35	8.17	10.60
20	12.0	9.63	1071.11	0.00	0.00	N/A	N/A
					Controlling	**1.46**	**1.89**

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA ENGINEERS
184 Court Street
BINGHAMTON, NEW YORK 13901
(607) 231-6600 Fax 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 3

Elmt Nmbr	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Vtotal (kip/ft)	Vdl only (kip/ft)	Vll only (kip/ft)	ϕVn (kip/ft)	1.75 INV	1.35 OPR
1	10.0	8.125	2.38	0.50	0.00	0.50	19.53	39.23	50.86
2	10.0	8.125	2.38	4.74	0.42	4.32	19.54	4.431	5.744
3	10.0	8.125	2.38	8.92	0.84	8.08	19.62	2.324	3.013
4	10.0	8.125	2.38	11.30	1.26	10.05	19.73	1.838	2.383
5	10.0	8.125	2.38	12.26	1.68	10.58	19.81	1.713	2.221
6	10.0	8.125	2.38	12.10	2.12	9.98	30.95	2.888	3.744
7	10.1	8.188	2.38	11.82	2.57	9.25	31.57	3.136	4.066
8	10.1	7.688	0.90	11.82	3.07	8.75	23.14	2.293	2.973
9	10.1	7.688	1.80	11.91	3.61	8.30	17.85	1.717	2.226
10	10.6	8.250	1.80	12.20	4.24	7.96	18.04	1.733	2.247
11	12.3	9.938	1.80	12.66	4.99	7.66	19.10	1.841	2.386
12	15.1	12.750	1.80	13.26	5.88	7.38	21.09	2.062	2.672
13	19.1	16.750	1.80	14.08	6.94	7.14	24.21	2.418	3.135
14	27.0	24.625	1.80	0.54	1.78	1.25	30.93	23.41	30.34
15	18.3	15.938	1.80	14.04	4.27	9.77	23.66	1.985	2.573
16	13.6	11.188	1.80	14.93	4.92	10.01	20.10	1.517	1.967
17	12.0	9.625	1.80	14.59	5.19	9.40	19.05	1.474	1.911
18	12.0	9.625	1.80	12.94	4.81	8.13	19.41	1.796	2.328
19	12.0	9.625	1.80	11.68	4.33	7.34	31.47	3.694	4.789
20	12.0	9.625	1.80	11.08	4.01	7.07	39.15	4.973	6.447
							controling:	**1.474**	**1.911**

$$F_d = 0.8 + \frac{1.6}{d} \le 1.3$$

$$F_n = 1 + \frac{N_u}{24 * thk}$$

$$\rho = \frac{A_s}{\phi bd} \le 0.02$$

$$\phi V_n = \phi 0.0316 b d F_{vp} \sqrt{f'c}\left(1.1 + 63\rho\right)\left(\frac{F_d F_n}{F_c}\right)$$

$$F_c = 1 \pm \left(\frac{d}{2 * rad}\right)$$

Shear Resistance Without Stirrups **AASHTO 12.10.4.2.5**

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 4

Technical Data & Load Factors

Culvert Span (S) =	28.00 ft.		
Crown Radius (Rad) =	33.82 ft.		
Bar Cover			
Outside Face (Cov_{out}) =	2.00 in		
Inside Face (Cov_{in}) =	1.50 in		
Design Section Length (b) =	12 in		
Compressive Strength (f_c) =	6.5 ksi		
Yield Strength (f_y) =	60 ksi		
Stirrup Yield Strength (f_{ystir}) =	60 ksi		
Circumferential Reinforcement Spa. (spa.) =	4.00 in		
Circumferential Reinforcement Provided (n) =	1	(n=1 for 1 layer, n=2 for multiple layers)	AASHTO
Reinforcement Type (Type) =	3	AASHTO Table	12.10.4.2.4d

1 - smooth wire or plain bar — 12.10.4.4d-1
2 - WWF (8" max spa. Smooth)
3 - WWF (deformed) or bar (deformed)

Resistance Factors:

ϕf - Flexure =	1.00	AASHTO Table 12.5.5-1
ϕr - Radial Tension =	0.90	
ϕv - Diag Tension =	0.90	
Radial Tension Process (F_{rp}) =	1.00	AASHTO 12.10.4.2.3
Diag Tension Process (F_{vp}) =	1.00	

Load Factors:

	IR	OR	
LL Factor	1.75	1.35	
γ_pDC (component)	1.31		(1.25*1.05 = 1.3125)
γ_pEH (hor. At rest earth pressure)	0.86		(0.9/1.05 = 0.857)
γ_pEV	1.37		(1.3*1.05 = 1.365)

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.		OF	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Design Force Summary LRFR LOAD RATING -HL93 Case 4

	Factored DC+EV+EH			Max Factored Total Load			Max Factored LL			
Node Number	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Thk at node (in)
1	-7.35	148.20	0.00	-25.11	404.28	0.03	-17.76	256.08	0.03	10.000
2	-7.40	145.37	0.42	-25.17	404.47	-0.06	-17.77	259.10	-0.48	10.000
3	-7.47	136.94	0.84	-25.17	405.79	-0.15	-17.70	268.85	-0.99	10.000
4	-7.59	122.94	1.26	-24.88	408.53	0.13	-17.29	285.59	-1.13	10.000
5	-7.78	103.28	1.68	-24.30	402.32	1.60	-16.52	299.04	-0.08	10.000
6	-8.03	77.90	2.12	-24.11	365.58	4.24	-16.08	287.68	2.13	10.000
7	-8.35	46.57	2.57	-24.90	288.64	7.74	-16.55	242.06	5.16	10.063
8	-8.71	8.90	3.07	-26.99	158.20	12.43	-18.28	149.30	9.37	10.063
9	-9.13	-35.60	3.61	-29.22	-44.56	16.18	-20.09	-8.96	12.57	10.063
10	-9.60	-87.80	4.24	-31.34	-275.32	19.26	-21.74	-187.51	15.02	10.625
11	-10.09	-149.20	4.99	-33.33	-560.56	21.53	-23.24	-411.36	16.54	12.313
12	-10.63	-221.57	5.88	-34.70	-852.23	22.04	-24.07	-630.66	16.16	15.125
13	-11.22	-306.83	6.94	-36.12	-1151.17	22.59	-24.91	-844.34	15.65	19.125
14	-13.21	-407.64	1.78	-39.90	-1457.64	3.87	-26.69	-1050.00	2.09	27.000
15	-15.00	-357.89	-4.27	-42.55	-1267.68	-16.25	-27.55	-909.79	-11.98	18.313
16	-15.14	-300.25	-4.92	-41.62	-1049.30	-18.18	-26.48	-749.05	-13.26	13.563
17	-15.27	-234.07	-5.19	-40.78	-810.48	-18.37	-25.51	-576.41	-13.17	12.000
18	-15.50	-147.08	-4.81	-40.18	-509.32	-16.55	-24.68	-362.23	-11.74	12.000
19	-15.78	-70.81	-4.33	-39.88	-248.47	-15.00	-24.10	-177.67	-10.67	12.000
20	-16.07	0.00	-4.01	-39.86	0.00	-14.27	-23.79	0.00	-10.26	12.000

Note: "-" thrust indicate compression

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 4

Node	Total Fac.	Factored DC+EH+EV			Factored LL			
Number	Nu (k/ft)	Nu_D (k/ft)	Mu_D (in-k/ft)	Vu_D (k/ft)	Nu_{LL} (k/ft)	$+Mu_{LL}$ (in-k/ft)	Vu_{LL} (k/ft)	Thick (in)
1	-25.11	-7.35	148.20	0.00	-17.76	256.08	0.03	10
2	-25.17	-7.40	145.37	0.42	-17.77	259.10	0.48	10
3	-25.17	-7.47	136.94	0.84	-17.70	268.85	0.99	10
4	-24.88	-7.59	122.94	1.26	-17.29	285.59	1.13	10
5	-24.30	-7.78	103.28	1.68	-16.52	299.04	0.08	10
6	-24.11	-8.03	77.90	2.12	-16.08	287.68	2.13	10
7	-24.90	-8.35	46.57	2.57	-16.55	242.06	5.16	10.063
8	-26.99	-8.71	8.90	3.07	-18.28	149.30	9.37	10.063
9	-29.22	-9.13	-35.60	3.61	-20.09	-8.96	12.57	10.063
10	-31.34	-9.60	-87.80	4.24	-21.74	-187.51	15.02	10.625
11	-33.33	-10.09	-149.20	4.99	-23.24	-411.36	16.54	12.313
12	-34.70	-10.63	-221.57	5.88	-24.07	-630.66	16.16	15.125
13	-36.12	-11.22	-306.83	6.94	-24.91	-844.34	15.65	19.125
14	-39.90	-13.21	-407.64	1.78	-26.69	-1050.00	2.09	27
15	-42.55	-15.00	-357.89	4.27	-27.55	-909.79	11.98	18.313
16	-41.62	-15.14	-300.25	4.92	-26.48	-749.05	13.26	13.563
17	-40.78	-15.27	-234.07	5.19	-25.51	-576.41	13.17	12
18	-40.18	-15.50	-147.08	4.81	-24.68	-362.23	11.74	12
19	-39.88	-15.78	-70.81	4.33	-24.10	-177.67	10.67	12
20	-39.86	-16.07	0.00	4.01	-23.79	0.00	10.26	12

note all shear values normalized to positive

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Node Number	thk (in)	d (in)	As'in (prov'd) (in^2 / ft)	As'out (prov'd) (in^2 / ft)
1	10.0	8.13	2.38	0.90
2	10.0	8.13	2.38	0.90
3	10.0	8.13	2.38	0.90
4	10.0	8.13	2.38	0.90
5	10.0	8.13	2.38	0.90
6	10.0	8.13	2.38	0.90
7	10.1	8.19	2.38	0.90
8	10.1	8.19	2.38	0.90
9	10.1	7.69	1.32	1.80
10	10.6	8.25	1.32	1.80
11	12.3	9.94	1.32	1.80
12	15.1	12.75	1.32	1.80
13	19.1	16.75	1.32	1.80
14	27.0	24.63	1.32	1.80
15	18.3	15.94	1.32	1.80
16	13.6	11.19	1.32	1.80
17	12.0	9.63	1.32	1.80
18	12.0	9.63	0.60	1.80
19	12.0	9.63	0.60	1.80
20	12.0	9.63	0.60	1.80

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 4

Node Number	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Total Fac. Nu (k/ft)	Phi Mn (in-k/ft)
1	10.0	8.13	2.38	-25.11	1071.84
2	10.0	8.13	2.38	-25.17	1071.99
3	10.0	8.13	2.38	-25.17	1071.98
4	10.0	8.13	2.38	-24.88	1071.27
5	10.0	8.13	2.38	-24.30	1069.83
6	10.0	8.13	2.38	-24.11	1069.35
7	10.1	8.19	2.38	-24.90	1081.07
8	10.1	8.19	2.38	-26.99	1086.29
9	10.1	7.69	1.80	-29.22	835.34
10	10.6	8.25	1.80	-31.34	911.08
11	12.3	9.94	1.80	-33.33	1127.88
12	15.1	12.75	1.80	-34.70	1485.84
13	19.1	16.75	1.80	-36.12	1997.79
14	27.0	24.63	1.80	-39.90	3033.17
15	18.3	15.94	1.80	-42.55	1939.98
16	13.6	11.19	1.80	-41.62	1321.72
17	12.0	9.63	1.80	-40.78	1117.24
18	12.0	9.63	1.80	-40.18	1114.99
19	12.0	9.63	1.80	-39.88	1113.85
20	12.0	9.63	1.80	-39.86	1113.80

AASHTO 12.10.4.2.4a

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 4

Node Number	thk (in)	d (in)	Phi Mn (in-k/ft)	Mu_D (in-k/ft)	$+Mu_{LL}$ (in-k/ft)	Inventory Rating	Operating Rating
1	10.0	8.13	1071.84	148.20	256.08	3.61	4.68
2	10.0	8.13	1071.99	145.37	259.10	3.58	4.64
3	10.0	8.13	1071.98	136.94	268.85	3.48	4.51
4	10.0	8.13	1071.27	122.94	285.59	3.32	4.30
5	10.0	8.13	1069.83	103.28	299.04	3.23	4.19
6	10.0	8.13	1069.35	77.90	287.68	3.45	4.47
7	10.1	8.19	1081.07	46.57	242.06	4.27	5.54
8	10.1	8.19	1086.29	8.90	149.30	7.22	9.35
9	10.1	7.69	835.34	-35.60	-8.96	89.25	115.70
10	10.6	8.25	911.08	-87.80	-187.51	4.39	5.69
11	12.3	9.94	1127.88	-149.20	-411.36	2.38	3.08
12	15.1	12.75	1485.84	-221.57	-630.66	2.00	2.60
13	19.1	16.75	1997.79	-306.83	-844.34	2.00	2.60
14	27.0	24.63	3033.17	-407.64	-1050.00	2.50	3.24
15	18.3	15.94	1939.98	-357.89	-909.79	1.74	2.25
16	13.6	11.19	1321.72	-300.25	-749.05	1.36	1.77
17	12.0	9.63	1117.24	-234.07	-576.41	1.53	1.99
18	12.0	9.63	1114.99	-147.08	-362.23	2.67	3.46
19	12.0	9.63	1113.85	-70.81	-177.67	5.87	7.61
20	12.0	9.63	1113.80	0.00	0.00	N/A	N/A
					Controlling	**1.36**	**1.77**

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA ENGINEERS
184 Court Street
BINGHAMTON, NEW YORK 13901
(607) 231-6600 Fax 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -HL93 Case 4

Elmt Nmbr	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Vtotal (kip/ft)	Vdl only (kip/ft)	Vll only (kip/ft)	ϕVn (kip/ft)	1.75 INV	1.35 OPR
1	10.0	8.125	2.38	0.03	0.00	0.03	19.99	793.1	1028
2	10.0	8.125	2.38	0.06	0.42	0.48	19.99	41.1	53.28
3	10.0	8.125	2.38	0.15	0.84	0.99	19.99	19.38	25.12
4	10.0	8.125	2.38	0.13	1.26	1.13	19.97	16.6	21.52
5	10.0	8.125	2.38	1.60	1.68	0.08	19.93	234.6	304.2
6	10.0	8.125	2.38	4.24	2.12	2.13	19.91	8.369	10.85
7	10.1	8.188	2.38	7.74	2.57	5.16	19.99	3.372	4.372
8	10.1	8.188	2.38	12.43	3.07	9.37	31.57	3.043	3.945
9	10.1	7.688	1.80	16.18	3.61	12.57	29.86	2.088	2.707
10	10.6	8.250	1.80	19.26	4.24	15.02	29.36	1.673	2.169
11	12.3	9.938	1.80	21.53	4.99	16.54	22.61	1.065	1.381
12	15.1	12.750	1.80	22.04	5.88	16.16	22.02	1.00	1.294
13	19.1	16.750	1.80	22.59	6.94	15.65	24.95	1.151	1.492
14	27.0	24.625	1.80	3.87	1.78	2.09	31.36	14.13	18.32
15	18.3	15.938	1.80	16.25	4.27	11.98	24.24	1.668	2.162
16	13.6	11.188	1.80	18.18	4.92	13.26	20.75	1.194	1.547
17	12.0	9.625	1.80	18.37	5.19	13.17	19.73	1.103	1.43
18	12.0	9.625	1.80	16.55	4.81	11.74	20.15	1.307	1.694
19	12.0	9.625	1.80	15.00	4.33	10.67	32.88	2.676	3.469
20	12.0	9.625	1.80	14.27	4.01	10.26	39.15	3.425	4.44
							controling:	**1.00**	**1.294**

$$F_d = 0.8 + \frac{1.6}{d} \le 1.3$$

$$F_n = 1 + \frac{N_u}{24 * thk}$$

$$\rho = \frac{A_s}{\phi bd} \le 0.02$$

$$\phi V_n = \phi 0.0316 b d F_{vp} \sqrt{f'c}\left(1.1 + 63\rho\right)\left(\frac{F_d F_n}{F_c}\right)$$

$$F_c = 1 \pm \left(\frac{d}{2 * rad}\right)$$

Shear Resistance Without Stirrups **AASHTO 12.10.4.2.5**

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -H20 Case 1

Technical Data & Load Factors

Culvert Span (S) =	28.00 ft.		
Crown Radius (Rad) =	33.82 ft.		
Bar Cover			
Outside Face (Cov_{out}) =	2.00 in		
Inside Face (Cov_{in}) =	1.50 in		
Design Section Length (b) =	12 in		
Compressive Strength (f_c) =	6.5 ksi		
Yield Strength (f_y) =	60 ksi		
Stirrup Yield Strength (f_{ystir}) =	60 ksi		
Circumferential Reinforcement Spa. (spa.) =	4.00 in		
Circumferential Reinforcement Provided (n) =	1	(n=1 for 1 layer, n=2 for multiple layers)	AASHTO
Reinforcement Type (Type) =	3	AASHTO Table	12.10.4.2.4d
1 - smooth wire or plain bar		12.10.4.4d-1	
2 - WWF (8" max spa. Smooth)			
3 - WWF (deformed) or bar (deformed)			

Resistance Factors:

ϕf - Flexure =	1.00	AASHTO Table 12.5.5-1
ϕr - Radial Tension =	0.90	
ϕv - Diag Tension =	0.90	
Radial Tension Process (F_{rp}) =	1.00	AASHTO 12.10.4.2.3
Diag Tension Process (F_{vp}) =	1.00	

Load Factors:

	IR	OR	
LL Factor	1.75	1.35	
γ_pDC (component)	1.31		(1.25*1.05 = 1.3125)
γ_pEH (hor. At rest earth pressure)	0.86		(0.9/1.05 = 0.857)
γ_pEV	1.37		(1.3*1.05 = 1.365)

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.		OF	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Design Force Summary LRFR LOAD RATING -H20 Case 1

	Factored DC+EV+EH			Max Factored Total Load			Max Factored LL			
Node Number	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Thk at node (in)
1	-7.35	148.20	0.00	-11.84	592.01	1.46	-4.48	443.81	1.46	10.000
2	-7.40	145.37	0.42	-13.63	547.02	5.24	-6.23	401.65	4.82	10.000
3	-7.47	136.94	0.84	-14.97	451.45	7.75	-7.50	314.51	6.91	10.000
4	-7.59	122.94	1.26	-15.60	339.41	8.30	-8.01	216.47	7.04	10.000
5	-7.78	103.28	1.68	-15.94	229.15	8.06	-8.16	125.87	6.38	10.000
6	-8.03	77.90	2.12	-16.35	123.34	8.00	-8.32	45.43	5.89	10.000
7	-8.35	46.57	2.57	-16.84	14.72	8.13	-8.50	-31.86	5.55	10.063
8	-8.71	8.90	3.07	-17.34	-94.42	8.22	-8.63	-103.32	5.15	10.063
9	-9.13	-35.60	3.61	-17.91	-205.58	8.43	-8.77	-169.99	4.82	10.063
10	-9.60	-87.80	4.24	-18.54	-320.27	8.76	-8.95	-232.47	4.52	10.625
11	-10.09	-149.20	4.99	-19.26	-440.34	9.23	-9.17	-291.14	4.24	12.313
12	-10.63	-221.57	5.88	-20.07	-567.58	9.84	-9.45	-346.01	3.96	15.125
13	-11.22	-306.83	6.94	-21.01	-703.97	10.66	-9.79	-397.14	3.72	19.125
14	-13.21	-407.64	1.78	-22.70	-853.26	0.79	-9.49	-445.62	-0.99	27.000
15	-15.00	-357.89	-4.27	-23.72	-733.08	-10.02	-8.72	-375.19	-5.75	18.313
16	-15.14	-300.25	-4.92	-23.34	-601.39	-10.81	-8.20	-301.14	-5.88	13.563
17	-15.27	-234.07	-5.19	-23.01	-461.38	-10.64	-7.74	-227.30	-5.44	12.000
18	-15.50	-147.08	-4.81	-22.77	-289.22	-9.44	-7.26	-142.14	-4.63	12.000
19	-15.78	-70.81	-4.33	-22.69	-140.78	-8.52	-6.91	-69.98	-4.19	12.000
20	-16.07	0.00	-4.01	-22.79	0.00	-8.07	-6.72	0.00	-4.06	12.000

Note: "-" thrust indicate compression

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -H20 Case 1

Node	Total Fac.	Factored DC+EH+EV			Factored LL			
Number	Nu (k/ft)	Nu_D (k/ft)	Mu_D (in-k/ft)	Vu_D (k/ft)	Nu_{LL} (k/ft)	$+Mu_{LL}$ (in-k/ft)	Vu_{LL} (k/ft)	Thick (in)
1	-11.84	-7.35	148.20	0.00	-4.48	443.81	1.46	10
2	-13.63	-7.40	145.37	0.42	-6.23	401.65	4.82	10
3	-14.97	-7.47	136.94	0.84	-7.50	314.51	6.91	10
4	-15.60	-7.59	122.94	1.26	-8.01	216.47	7.04	10
5	-15.94	-7.78	103.28	1.68	-8.16	125.87	6.38	10
6	-16.35	-8.03	77.90	2.12	-8.32	45.43	5.89	10
7	-16.84	-8.35	46.57	2.57	-8.50	-31.86	5.55	10.063
8	-17.34	-8.71	8.90	3.07	-8.63	-103.32	5.15	10.063
9	-17.91	-9.13	-35.60	3.61	-8.77	-169.99	4.82	10.063
10	-18.54	-9.60	-87.80	4.24	-8.95	-232.47	4.52	10.625
11	-19.26	-10.09	-149.20	4.99	-9.17	-291.14	4.24	12.313
12	-20.07	-10.63	-221.57	5.88	-9.45	-346.01	3.96	15.125
13	-21.01	-11.22	-306.83	6.94	-9.79	-397.14	3.72	19.125
14	-22.70	-13.21	-407.64	1.78	-9.49	-445.62	0.99	27
15	-23.72	-15.00	-357.89	4.27	-8.72	-375.19	5.75	18.313
16	-23.34	-15.14	-300.25	4.92	-8.20	-301.14	5.88	13.563
17	-23.01	-15.27	-234.07	5.19	-7.74	-227.30	5.44	12
18	-22.77	-15.50	-147.08	4.81	-7.26	-142.14	4.63	12
19	-22.69	-15.78	-70.81	4.33	-6.91	-69.98	4.19	12
20	-22.79	-16.07	0.00	4.01	-6.72	0.00	4.06	12

note all shear values normalized to positive

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2014.059.004
DESCRIPTION 28x10 Arch
SHEET NO. OF SCALE
CALCULATED BY YL DATE 11/25/2014
CHECKED BY DATE

Node Number	thk (in)	d (in)	As'in (prov'd) (in^2 / ft)	As'out (prov'd) (in^2 / ft)
1	10.0	8.13	2.38	0.90
2	10.0	8.13	2.38	0.90
3	10.0	8.13	2.38	0.90
4	10.0	8.13	2.38	0.90
5	10.0	8.13	2.38	0.90
6	10.0	8.13	2.38	0.90
7	10.1	8.19	2.38	0.90
8	10.1	7.69	2.38	0.90
9	10.1	7.69	1.32	1.80
10	10.6	8.25	1.32	1.80
11	12.3	9.94	1.32	1.80
12	15.1	12.75	1.32	1.80
13	19.1	16.75	1.32	1.80
14	27.0	24.63	1.32	1.80
15	18.3	15.94	1.32	1.80
16	13.6	11.19	1.32	1.80
17	12.0	9.63	1.32	1.80
18	12.0	9.63	0.60	1.80
19	12.0	9.63	0.60	1.80
20	12.0	9.63	0.60	1.80

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -H20 Case 1

Node Number	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Total Fac. Nu (k/ft)	Phi Mn (in-k/ft)
1	10.0	8.13	2.38	-11.84	1037.71
2	10.0	8.13	2.38	-13.63	1042.48
3	10.0	8.13	2.38	-14.97	1046.02
4	10.0	8.13	2.38	-15.60	1047.66
5	10.0	8.13	2.38	-15.94	1048.54
6	10.0	8.13	2.38	-16.35	1049.60
7	10.1	8.19	2.38	-16.84	1060.40
8	10.1	7.69	0.90	-17.34	464.03
9	10.1	7.69	1.80	-17.91	800.85
10	10.6	8.25	1.80	-18.54	868.75
11	12.3	9.94	1.80	-19.26	1069.76
12	15.1	12.75	1.80	-20.07	1405.10
13	19.1	16.75	1.80	-21.01	1884.41
14	27.0	24.63	1.80	-22.70	2837.11
15	18.3	15.94	1.80	-23.72	1807.62
16	13.6	11.19	1.80	-23.34	1236.49
17	12.0	9.63	1.80	-23.01	1048.11
18	12.0	9.63	1.80	-22.77	1047.14
19	12.0	9.63	1.80	-22.69	1046.83
20	12.0	9.63	1.80	-22.79	1047.22

AASHTO 12.10.4.2.4a

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -H20 Case 1

Node Number	thk (in)	d (in)	Phi Mn (in-k/ft)	Mu_D (in-k/ft)	$+Mu_{LL}$ (in-k/ft)	Inventory Rating	Operating Rating
1	10.0	8.13	1037.71	148.20	443.81	2.00	2.60
2	10.0	8.13	1042.48	145.37	401.65	2.23	2.90
3	10.0	8.13	1046.02	136.94	314.51	2.89	3.75
4	10.0	8.13	1047.66	122.94	216.47	4.27	5.54
5	10.0	8.13	1048.54	103.28	125.87	7.51	9.74
6	10.0	8.13	1049.60	77.90	45.43	21.39	27.72
7	10.1	8.19	1060.40	46.57	-31.86	34.75	45.04
8	10.1	7.69	464.03	8.90	-103.32	4.58	5.93
9	10.1	7.69	800.85	-35.60	-169.99	4.50	5.84
10	10.6	8.25	868.75	-87.80	-232.47	3.36	4.35
11	12.3	9.94	1069.76	-149.20	-291.14	3.16	4.10
12	15.1	12.75	1405.10	-221.57	-346.01	3.42	4.43
13	19.1	16.75	1884.41	-306.83	-397.14	3.97	5.15
14	27.0	24.63	2837.11	-407.64	-445.62	5.45	7.07
15	18.3	15.94	1807.62	-357.89	-375.19	3.86	5.01
16	13.6	11.19	1236.49	-300.25	-301.14	3.11	4.03
17	12.0	9.63	1048.11	-234.07	-227.30	3.58	4.64
18	12.0	9.63	1047.14	-147.08	-142.14	6.33	8.21
19	12.0	9.63	1046.83	-70.81	-69.98	13.95	18.08
20	12.0	9.63	1047.22	0.00	0.00	N/A	N/A
					Controlling	**2.00**	**2.60**

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA ENGINEERS
184 Court Street
BINGHAMTON, NEW YORK 13901
(607) 231-6600 Fax 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -H20 Case 1

Elmt Nmbr	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Vtotal (kip/ft)	Vdl only (kip/ft)	Vll only (kip/ft)	ϕVn (kip/ft)	1.75 INV	1.35 OPR
1	10.0	8.125	2.38	1.46	0.00	1.46	18.99	13	16.86
2	10.0	8.125	2.38	5.24	0.42	4.82	19.12	3.878	5.027
3	10.0	8.125	2.38	7.75	0.84	6.91	19.22	2.661	3.449
4	10.0	8.125	2.38	8.30	1.26	7.04	19.27	2.559	3.317
5	10.0	8.125	2.38	8.06	1.68	6.38	19.30	2.76	3.578
6	10.0	8.125	2.38	8.00	2.12	5.89	28.94	4.558	5.908
7	10.1	8.188	2.38	8.13	2.57	5.55	31.57	5.223	6.771
8	10.1	7.688	0.90	8.22	3.07	5.15	23.28	3.922	5.084
9	10.1	7.688	1.80	8.43	3.61	4.82	17.84	2.953	3.828
10	10.6	8.250	1.80	8.76	4.24	4.52	17.56	2.946	3.819
11	12.3	9.938	1.80	9.23	4.99	4.24	18.64	3.221	4.176
12	15.1	12.750	1.80	9.84	5.88	3.96	20.66	3.74	4.842
13	19.1	16.750	1.80	10.66	6.94	3.72	23.81	4.537	5.881
14	27.0	24.625	1.80	0.79	1.78	0.99	30.57	28.94	37.51
15	18.3	15.938	1.80	10.02	4.27	5.75	23.29	3.309	4.289
16	13.6	11.188	1.80	10.81	4.92	5.88	19.72	2.515	3.26
17	12.0	9.625	1.80	10.64	5.19	5.44	18.66	2.474	3.207
18	12.0	9.625	1.80	9.44	4.81	4.63	19.14	3.094	4.011
19	12.0	9.625	1.80	8.52	4.33	4.19	31.22	6.423	8.326
20	12.0	9.625	1.80	8.07	4.01	4.06	39.15	8.663	11.23
							controling:	**2.47**	**3.207**

$$F_d = 0.8 + \frac{1.6}{d} \le 1.3$$

$$F_n = 1 + \frac{N_u}{24 * thk}$$

$$\rho = \frac{A_s}{\phi bd} \le 0.02$$

$$\phi V_n = \phi 0.0316 b d F_{vp} \sqrt{f'c}\left(1.1 + 63\rho\right)\left(\frac{F_d F_n}{F_c}\right)$$

$$F_c = 1 \pm \left(\frac{d}{2 * rad}\right)$$

Shear Resistance Without Stirrups **AASHTO 12.10.4.2.5**

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -H20 Case 2

Technical Data & Load Factors

Culvert Span (S) =	28.00 ft.		
Crown Radius (Rad) =	33.82 ft.		
Bar Cover			
Outside Face (Cov_{out}) =	2.00 in		
Inside Face (Cov_{in}) =	1.50 in		
Design Section Length (b) =	12 in		
Compressive Strength (f_c) =	6.5 ksi		
Yield Strength (f_y) =	60 ksi		
Stirrup Yield Strength (f_{ystir}) =	60 ksi		
Circumferential Reinforcement Spa. (spa.) =	4.00 in		
Circumferential Reinforcement Provided (n) =	1	(n=1 for 1 layer, n=2 for multiple layers)	AASHTO
Reinforcement Type (Type) =	3	AASHTO Table 12.10.4.4d-1	12.10.4.2.4d

1 - smooth wire or plain bar
2 - WWF (8" max spa. Smooth)
3 - WWF (deformed) or bar (deformed)

Resistance Factors:

ϕf - Flexure =	1.00	AASHTO Table 12.5.5-1
ϕr - Radial Tension =	0.90	
ϕv - Diag Tension =	0.90	
Radial Tension Process (F_{rp}) =	1.00	AASHTO 12.10.4.2.3
Diag Tension Process (F_{vp}) =	1.00	

Load Factors:

	IR	OR	
LL Factor	1.75	1.35	
γ_pDC (component)	1.31		(1.25*1.05 = 1.3125)
γ_pEH (hor. At rest earth pressure)	0.86		(0.9/1.05 = 0.857)
γ_pEV	1.37		(1.3*1.05 = 1.365)

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.		OF	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Design Force Summary LRFR LOAD RATING -H20 Case 2

	Factored DC+EV+EH			Max Factored Total Load			Max Factored LL			
Node Number	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Thk at node (in)
1	-7.35	148.20	0.00	-18.90	280.14	0.01	-11.55	131.94	0.01	10.000
2	-7.40	145.37	0.42	-18.91	279.54	0.08	-11.51	134.17	-0.34	10.000
3	-7.47	136.94	0.84	-18.92	278.09	0.09	-11.45	141.14	-0.75	10.000
4	-7.59	122.94	1.26	-18.86	277.09	0.02	-11.27	154.15	-1.24	10.000
5	-7.78	103.28	1.68	-18.58	277.61	0.36	-10.80	174.32	-1.32	10.000
6	-8.03	77.90	2.12	-17.90	267.32	2.11	-9.87	189.42	-0.01	10.000
7	-8.35	46.57	2.57	-17.58	221.12	5.11	-9.23	174.55	2.53	10.063
8	-8.71	8.90	3.07	-18.68	130.44	8.58	-9.97	121.54	5.51	10.063
9	-9.13	-35.60	3.61	-20.85	-8.83	12.55	-11.72	26.77	8.94	10.063
10	-9.60	-87.80	4.24	-22.49	-205.87	14.84	-12.89	-118.07	10.60	10.625
11	-10.09	-149.20	4.99	-23.40	-406.61	15.18	-13.31	-257.41	10.18	12.313
12	-10.63	-221.57	5.88	-24.37	-612.55	15.56	-13.75	-390.98	9.68	15.125
13	-11.22	-306.83	6.94	-25.43	-823.58	16.07	-14.21	-516.76	9.13	19.125
14	-13.21	-407.64	1.78	-28.42	-1043.21	2.98	-15.21	-635.57	1.20	27.000
15	-15.00	-357.89	-4.27	-30.65	-912.30	-11.38	-15.65	-554.41	-7.11	18.313
16	-15.14	-300.25	-4.92	-30.24	-757.18	-13.04	-15.10	-456.92	-8.11	13.563
17	-15.27	-234.07	-5.19	-29.89	-584.48	-13.27	-14.61	-350.41	-8.08	12.000
18	-15.50	-147.08	-4.81	-29.64	-367.01	-11.94	-14.13	-219.92	-7.13	12.000
19	-15.78	-70.81	-4.33	-29.55	-178.98	-10.81	-13.77	-108.17	-6.48	12.000
20	-16.07	0.00	-4.01	-29.61	0.00	-10.27	-13.54	0.00	-6.27	12.000

Note: "-" thrust indicate compression

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2014.059.004
DESCRIPTION 28x10 Arch
SHEET NO. OF SCALE
CALCULATED BY YL DATE 11/25/2014
CHECKED BY DATE

LRFR LOAD RATING -H20 Case 2

Node	Total Fac.	Factored DC+EH+EV			Factored LL			
Number	Nu (k/ft)	Nu_D (k/ft)	Mu_D (in-k/ft)	Vu_D (k/ft)	Nu_{LL} (k/ft)	$+Mu_{LL}$ (in-k/ft)	Vu_{LL} (k/ft)	Thick (in)
1	-18.90	-7.35	148.20	0.00	-11.55	131.94	0.01	10
2	-18.91	-7.40	145.37	0.42	-11.51	134.17	0.34	10
3	-18.92	-7.47	136.94	0.84	-11.45	141.14	0.75	10
4	-18.86	-7.59	122.94	1.26	-11.27	154.15	1.24	10
5	-18.58	-7.78	103.28	1.68	-10.80	174.32	1.32	10
6	-17.90	-8.03	77.90	2.12	-9.87	189.42	0.01	10
7	-17.58	-8.35	46.57	2.57	-9.23	174.55	2.53	10.063
8	-18.68	-8.71	8.90	3.07	-9.97	121.54	5.51	10.063
9	-20.85	-9.13	-35.60	3.61	-11.72	26.77	8.94	10.063
10	-22.49	-9.60	-87.80	4.24	-12.89	-118.07	10.60	10.625
11	-23.40	-10.09	-149.20	4.99	-13.31	-257.41	10.18	12.313
12	-24.37	-10.63	-221.57	5.88	-13.75	-390.98	9.68	15.125
13	-25.43	-11.22	-306.83	6.94	-14.21	-516.76	9.13	19.125
14	-28.42	-13.21	-407.64	1.78	-15.21	-635.57	1.20	27
15	-30.65	-15.00	-357.89	4.27	-15.65	-554.41	7.11	18.313
16	-30.24	-15.14	-300.25	4.92	-15.10	-456.92	8.11	13.563
17	-29.89	-15.27	-234.07	5.19	-14.61	-350.41	8.08	12
18	-29.64	-15.50	-147.08	4.81	-14.13	-219.92	7.13	12
19	-29.55	-15.78	-70.81	4.33	-13.77	-108.17	6.48	12
20	-29.61	-16.07	0.00	4.01	-13.54	0.00	6.27	12

note all shear values normalized to positive

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2014.059.004
DESCRIPTION 28x10 Arch
SHEET NO. OF SCALE
CALCULATED BY YL DATE 11/25/2014
CHECKED BY DATE

Node Number	thk (in)	d (in)	As'in (prov'd) (in^2 / ft)	As'out (prov'd) (in^2 / ft)
1	10.0	8.13	2.38	0.90
2	10.0	8.13	2.38	0.90
3	10.0	8.13	2.38	0.90
4	10.0	8.13	2.38	0.90
5	10.0	8.13	2.38	0.90
6	10.0	8.13	2.38	0.90
7	10.1	8.19	2.38	0.90
8	10.1	8.19	2.38	0.90
9	10.1	7.69	1.32	1.80
10	10.6	8.25	1.32	1.80
11	12.3	9.94	1.32	1.80
12	15.1	12.75	1.32	1.80
13	19.1	16.75	1.32	1.80
14	27.0	24.63	1.32	1.80
15	18.3	15.94	1.32	1.80
16	13.6	11.19	1.32	1.80
17	12.0	9.63	1.32	1.80
18	12.0	9.63	0.60	1.80
19	12.0	9.63	0.60	1.80
20	12.0	9.63	0.60	1.80

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -H20 Case 2

Node Number	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Total Fac. Nu (k/ft)	Phi Mn (in-k/ft)
1	10.0	8.13	2.38	-18.90	1056.21
2	10.0	8.13	2.38	-18.91	1056.23
3	10.0	8.13	2.38	-18.92	1056.25
4	10.0	8.13	2.38	-18.86	1056.11
5	10.0	8.13	2.38	-18.58	1055.37
6	10.0	8.13	2.38	-17.90	1053.62
7	10.1	8.19	2.38	-17.58	1062.32
8	10.1	8.19	2.38	-18.68	1065.21
9	10.1	7.69	1.80	-20.85	810.02
10	10.6	8.25	1.80	-22.49	882.06
11	12.3	9.94	1.80	-23.40	1087.18
12	15.1	12.75	1.80	-24.37	1429.17
13	19.1	16.75	1.80	-25.43	1917.90
14	27.0	24.63	1.80	-28.42	2902.80
15	18.3	15.94	1.80	-30.65	1856.99
16	13.6	11.19	1.80	-30.24	1269.23
17	12.0	9.63	1.80	-29.89	1075.43
18	12.0	9.63	1.80	-29.64	1074.46
19	12.0	9.63	1.80	-29.55	1074.10
20	12.0	9.63	1.80	-29.61	1074.35

AASHTO 12.10.4.2.4a

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -H20 Case 2

Node Number	thk (in)	d (in)	Phi Mn (in-k/ft)	Mu_D (in-k/ft)	$+Mu_{LL}$ (in-k/ft)	Inventory Rating	Operating Rating
1	10.0	8.13	1056.21	148.20	131.94	6.88	8.92
2	10.0	8.13	1056.23	145.37	134.17	6.79	8.80
3	10.0	8.13	1056.25	136.94	141.14	6.51	8.44
4	10.0	8.13	1056.11	122.94	154.15	6.05	7.85
5	10.0	8.13	1055.37	103.28	174.32	5.46	7.08
6	10.0	8.13	1053.62	77.90	189.42	5.15	6.68
7	10.1	8.19	1062.32	46.57	174.55	5.82	7.54
8	10.1	8.19	1065.21	8.90	121.54	8.69	11.27
9	10.1	7.69	810.02	-35.60	26.77	31.59	40.95
10	10.6	8.25	882.06	-87.80	-118.07	6.73	8.72
11	12.3	9.94	1087.18	-149.20	-257.41	3.64	4.72
12	15.1	12.75	1429.17	-221.57	-390.98	3.09	4.00
13	19.1	16.75	1917.90	-306.83	-516.76	3.12	4.04
14	27.0	24.63	2902.80	-407.64	-635.57	3.93	5.09
15	18.3	15.94	1856.99	-357.89	-554.41	2.70	3.51
16	13.6	11.19	1269.23	-300.25	-456.92	2.12	2.75
17	12.0	9.63	1075.43	-234.07	-350.41	2.40	3.11
18	12.0	9.63	1074.46	-147.08	-219.92	4.22	5.47
19	12.0	9.63	1074.10	-70.81	-108.17	9.27	12.02
20	12.0	9.63	1074.35	0.00	0.00	N/A	N/A
					Controlling	**2.12**	**2.75**

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA ENGINEERS
184 Court Street
BINGHAMTON, NEW YORK 13901
(607) 231-6600 Fax 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -H20 Case 2

Elmt Nmbr	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Vtotal (kip/ft)	Vdl only (kip/ft)	Vll only (kip/ft)	ϕVn (kip/ft)	1.75 INV	1.35 OPR
1	10.0	8.125	2.38	0.01	0.00	0.01	19.52	1960	2540
2	10.0	8.125	2.38	0.08	0.42	0.34	19.52	55.63	72.12
3	10.0	8.125	2.38	0.09	0.84	0.75	19.52	25.05	32.47
4	10.0	8.125	2.38	0.02	1.26	1.24	19.52	14.75	19.11
5	10.0	8.125	2.38	0.36	1.68	1.32	19.50	13.54	17.55
6	10.0	8.125	2.38	2.11	2.12	0.01	19.44	2123	2753
7	10.1	8.188	2.38	5.11	2.57	2.53	19.44	6.659	8.633
8	10.1	8.188	2.38	8.58	3.07	5.51	29.86	4.859	6.298
9	10.1	7.688	1.80	12.55	3.61	8.94	29.86	2.935	3.805
10	10.6	8.250	1.80	14.84	4.24	10.60	28.87	2.322	3.01
11	12.3	9.938	1.80	15.18	4.99	10.18	21.44	1.615	2.094
12	15.1	12.750	1.80	15.56	5.88	9.68	21.14	1.58	2.044
13	19.1	16.750	1.80	16.07	6.94	9.13	24.30	1.901	2.465
14	27.0	24.625	1.80	2.98	1.78	1.20	30.83	24.15	31.31
15	18.3	15.938	1.80	11.38	4.27	7.11	23.64	2.725	3.532
16	13.6	11.188	1.80	13.04	4.92	8.11	20.11	1.871	2.426
17	12.0	9.625	1.80	13.27	5.19	8.08	19.08	1.718	2.227
18	12.0	9.625	1.80	11.94	4.81	7.13	19.56	2.068	2.681
19	12.0	9.625	1.80	10.81	4.33	6.48	31.98	4.269	5.534
20	12.0	9.625	1.80	10.27	4.01	6.27	39.15	5.61	7.272
							controling:	**1.58**	**2.044**

$$F_d = 0.8 + \frac{1.6}{d} \le 1.3$$

$$F_n = 1 + \frac{N_u}{24 * thk}$$

$$\rho = \frac{A_s}{\phi bd} \le 0.02$$

$$\phi V_n = \phi 0.0316 b d F_{vp} \sqrt{f'c}\left(1.1 + 63\rho\right)\left(\frac{F_d F_n}{F_c}\right)$$

$$F_c = 1 \pm \left(\frac{d}{2 * rad}\right)$$

Shear Resistance Without Stirrups **AASHTO 12.10.4.2.5**

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3S2 Case 1

Technical Data & Load Factors

Culvert Span (S) =	28.00 ft.		
Crown Radius (Rad) =	33.82 ft.		
Bar Cover			
Outside Face (Cov_{out}) =	2.00 in		
Inside Face (Cov_{in}) =	1.50 in		
Design Section Length (b) =	12 in		
Compressive Strength (f_c) =	6.5 ksi		
Yield Strength (f_y) =	60 ksi		
Stirrup Yield Strength (f_{ystir}) =	60 ksi		
Circumferential Reinforcement Spa. (spa.) =	4.00 in		
Circumferential Reinforcement Provided (n) =	1	(n=1 for 1 layer, n=2 for multiple layers)	AASHTO
Reinforcement Type (Type) =	3	AASHTO Table 12.10.4.4d-1	12.10.4.2.4d

1 - smooth wire or plain bar
2 - WWF (8" max spa. Smooth)
3 - WWF (deformed) or bar (deformed)

Resistance Factors:

ϕf - Flexure =	1.00	AASHTO Table 12.5.5-1
ϕr - Radial Tension =	0.90	
ϕv - Diag Tension =	0.90	
Radial Tension Process (F_{rp}) =	1.00	AASHTO 12.10.4.2.3
Diag Tension Process (F_{vp}) =	1.00	

Load Factors:

	IR	OR	
LL Factor		1.35	
γ_pDC (component)	1.31		(1.25*1.05 = 1.3125)
γ_pEH (hor. At rest earth pressure)	0.86		(0.9/1.05 = 0.857)
γ_pEV	1.37		(1.3*1.05 = 1.365)

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.		OF	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Design Force Summary LRFR LOAD RATING -3S2 Case 1

	Factored DC+EV+EH			Max Factored Total Load			Max Factored LL			
Node Number	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Thk at node (in)
1	-7.35	148.20	0.00	-13.22	382.26	-0.09	-5.87	234.06	-0.09	10.000
2	-7.40	145.37	0.42	-13.37	369.08	2.05	-5.97	223.72	1.63	10.000
3	-7.47	136.94	0.84	-13.87	327.26	3.87	-6.40	190.32	3.03	10.000
4	-7.59	122.94	1.26	-14.61	265.39	5.03	-7.02	142.45	3.77	10.000
5	-7.78	103.28	1.68	-15.15	192.46	5.56	-7.37	89.17	3.88	10.000
6	-8.03	77.90	2.12	-15.51	116.35	5.62	-7.48	38.45	3.51	10.000
7	-8.35	46.57	2.57	-15.87	41.77	5.65	-7.53	-4.80	3.07	10.063
8	-8.71	8.90	3.07	-16.34	-35.03	5.88	-7.62	-43.93	2.81	10.063
9	-9.13	-35.60	3.61	-16.93	-115.74	6.42	-7.79	-80.15	2.82	10.063
10	-9.60	-87.80	4.24	-17.64	-207.19	7.48	-8.04	-119.39	3.24	10.625
11	-10.09	-149.20	4.99	-18.09	-316.30	8.75	-8.00	-167.10	3.75	12.313
12	-10.63	-221.57	5.88	-18.90	-441.55	10.45	-8.28	-219.98	4.56	15.125
13	-11.22	-306.83	6.94	-20.23	-596.26	12.29	-9.01	-289.43	5.34	19.125
14	-13.21	-407.64	1.78	-23.07	-770.77	2.56	-9.86	-363.13	0.78	27.000
15	-15.00	-357.89	-4.27	-25.26	-671.53	-8.51	-10.26	-313.64	-4.23	18.313
16	-15.14	-300.25	-4.92	-25.03	-557.03	-9.62	-9.89	-256.78	-4.69	13.563
17	-15.27	-234.07	-5.19	-24.83	-429.71	-9.78	-9.55	-195.64	-4.59	12.000
18	-15.50	-147.08	-4.81	-24.72	-269.42	-8.79	-9.22	-122.34	-3.99	12.000
19	-15.78	-70.81	-4.33	-24.73	-131.05	-7.93	-8.95	-60.25	-3.60	12.000
20	-16.07	0.00	-4.01	-24.83	0.00	-7.50	-8.76	0.00	-3.49	12.000

Note: "-" thrust indicate compression

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3S2 Case 1

Node	Total Fac.	Factored DC+EH+EV			Factored LL			
Number	Nu (k/ft)	Nu_D (k/ft)	Mu_D (in-k/ft)	Vu_D (k/ft)	Nu_{LL} (k/ft)	$+Mu_{LL}$ (in-k/ft)	Vu_{LL} (k/ft)	Thick (in)
1	-13.22	-7.35	148.20	0.00	-5.87	234.06	0.09	10
2	-13.37	-7.40	145.37	0.42	-5.97	223.72	1.63	10
3	-13.87	-7.47	136.94	0.84	-6.40	190.32	3.03	10
4	-14.61	-7.59	122.94	1.26	-7.02	142.45	3.77	10
5	-15.15	-7.78	103.28	1.68	-7.37	89.17	3.88	10
6	-15.51	-8.03	77.90	2.12	-7.48	38.45	3.51	10
7	-15.87	-8.35	46.57	2.57	-7.53	-4.80	3.07	10.063
8	-16.34	-8.71	8.90	3.07	-7.62	-43.93	2.81	10.063
9	-16.93	-9.13	-35.60	3.61	-7.79	-80.15	2.82	10.063
10	-17.64	-9.60	-87.80	4.24	-8.04	-119.39	3.24	10.625
11	-18.09	-10.09	-149.20	4.99	-8.00	-167.10	3.75	12.313
12	-18.90	-10.63	-221.57	5.88	-8.28	-219.98	4.56	15.125
13	-20.23	-11.22	-306.83	6.94	-9.01	-289.43	5.34	19.125
14	-23.07	-13.21	-407.64	1.78	-9.86	-363.13	0.78	27
15	-25.26	-15.00	-357.89	4.27	-10.26	-313.64	4.23	18.313
16	-25.03	-15.14	-300.25	4.92	-9.89	-256.78	4.69	13.563
17	-24.83	-15.27	-234.07	5.19	-9.55	-195.64	4.59	12
18	-24.72	-15.50	-147.08	4.81	-9.22	-122.34	3.99	12
19	-24.73	-15.78	-70.81	4.33	-8.95	-60.25	3.60	12
20	-24.83	-16.07	0.00	4.01	-8.76	0.00	3.49	12

note all shear values normalized to positive

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Node Number	thk (in)	d (in)	As'in (prov'd) (in^2 / ft)	As'out (prov'd) (in^2 / ft)
1	10.0	8.13	2.38	0.90
2	10.0	8.13	2.38	0.90
3	10.0	8.13	2.38	0.90
4	10.0	8.13	2.38	0.90
5	10.0	8.13	2.38	0.90
6	10.0	8.13	2.38	0.90
7	10.1	8.19	2.38	0.90
8	10.1	7.69	2.38	0.90
9	10.1	7.69	1.32	1.80
10	10.6	8.25	1.32	1.80
11	12.3	9.94	1.32	1.80
12	15.1	12.75	1.32	1.80
13	19.1	16.75	1.32	1.80
14	27.0	24.63	1.32	1.80
15	18.3	15.94	1.32	1.80
16	13.6	11.19	1.32	1.80
17	12.0	9.63	1.32	1.80
18	12.0	9.63	0.60	1.80
19	12.0	9.63	0.60	1.80
20	12.0	9.63	0.60	1.80

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3S2 Case 1

Node Number	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Total Fac. Nu (k/ft)	Phi Mn (in-k/ft)
1	10.0	8.13	2.38	-13.22	1041.38
2	10.0	8.13	2.38	-13.37	1041.78
3	10.0	8.13	2.38	-13.87	1043.11
4	10.0	8.13	2.38	-14.61	1045.06
5	10.0	8.13	2.38	-15.15	1046.46
6	10.0	8.13	2.38	-15.51	1047.42
7	10.1	8.19	2.38	-15.87	1057.85
8	10.1	7.69	0.90	-16.34	460.04
9	10.1	7.69	1.80	-16.93	797.78
10	10.6	8.25	1.80	-17.64	865.67
11	12.3	9.94	1.80	-18.09	1064.77
12	15.1	12.75	1.80	-18.90	1398.51
13	19.1	16.75	1.80	-20.23	1878.43
14	27.0	24.63	1.80	-23.07	2841.44
15	18.3	15.94	1.80	-25.26	1818.65
16	13.6	11.19	1.80	-25.03	1244.60
17	12.0	9.63	1.80	-24.83	1055.40
18	12.0	9.63	1.80	-24.72	1054.98
19	12.0	9.63	1.80	-24.73	1055.01
20	12.0	9.63	1.80	-24.83	1055.43

AASHTO 12.10.4.2.4a

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3S2 Case 1

Node Number	thk (in)	d (in)	Phi Mn (in-k/ft)	Mu_D (in-k/ft)	$+Mu_{LL}$ (in-k/ft)		Operating Rating
1	10.0	8.13	1041.38	148.20	234.06		4.95
2	10.0	8.13	1041.78	145.37	223.72		5.19
3	10.0	8.13	1043.11	136.94	190.32		6.17
4	10.0	8.13	1045.06	122.94	142.45		8.39
5	10.0	8.13	1046.46	103.28	89.17		13.71
6	10.0	8.13	1047.42	77.90	38.45		32.69
7	10.1	8.19	1057.85	46.57	-4.80		298.04
8	10.1	7.69	460.04	8.90	-43.93		13.84
9	10.1	7.69	797.78	-35.60	-80.15		12.33
10	10.6	8.25	865.67	-87.80	-119.39		8.45
11	12.3	9.94	1064.77	-149.20	-167.10		7.10
12	15.1	12.75	1398.51	-221.57	-219.98		6.94
13	19.1	16.75	1878.43	-306.83	-289.43		7.04
14	27.0	24.63	2841.44	-407.64	-363.13		8.69
15	18.3	15.94	1818.65	-357.89	-313.64		6.04
16	13.6	11.19	1244.60	-300.25	-256.78		4.77
17	12.0	9.63	1055.40	-234.07	-195.64		5.44
18	12.0	9.63	1054.98	-147.08	-122.34		9.62
19	12.0	9.63	1055.01	-70.81	-60.25		21.18
20	12.0	9.63	1055.43	0.00	0.00		N/A
					Controlling		**4.77**

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA ENGINEERS
184 Court Street
BINGHAMTON, NEW YORK 13901
(607) 231-6600 Fax 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3S2 Case 1

Elmt Nmbr	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Vtotal (kip/ft)	Vdl only (kip/ft)	Vll only (kip/ft)	ϕVn (kip/ft)		1.35 OPR
1	10.0	8.125	2.38	0.09	0.00	0.09	19.09		276
2	10.0	8.125	2.38	2.05	0.42	1.63	19.10		14.84
3	10.0	8.125	2.38	3.87	0.84	3.03	19.14		7.824
4	10.0	8.125	2.38	5.03	1.26	3.77	19.20		6.161
5	10.0	8.125	2.38	5.56	1.68	3.88	19.24		5.864
6	10.0	8.125	2.38	5.62	2.12	3.51	23.77		8.005
7	10.1	8.188	2.38	5.65	2.57	3.07	31.57		12.23
8	10.1	7.688	0.90	5.88	3.07	2.81	29.86		12.35
9	10.1	7.688	1.80	6.42	3.61	2.82	23.32		9.073
10	10.6	8.250	1.80	7.48	4.24	3.24	17.50		5.299
11	12.3	9.938	1.80	8.75	4.99	3.75	18.57		4.689
12	15.1	12.750	1.80	10.45	5.88	4.56	20.59		4.178
13	19.1	16.750	1.80	12.29	6.94	5.34	25.10		4.406
14	27.0	24.625	1.80	2.56	1.78	0.78	30.59		47.85
15	18.3	15.938	1.80	8.51	4.27	4.23	23.37		5.85
16	13.6	11.188	1.80	9.62	4.92	4.69	19.81		4.113
17	12.0	9.625	1.80	9.78	5.19	4.59	18.77		3.835
18	12.0	9.625	1.80	8.79	4.81	3.99	19.52		4.783
19	12.0	9.625	1.80	7.93	4.33	3.60	32.21		10.03
20	12.0	9.625	1.80	7.50	4.01	3.49	39.15		13.04
								controling:	**3.835**

$$F_d = 0.8 + \frac{1.6}{d} \le 1.3$$

$$F_n = 1 + \frac{N_u}{24 * thk}$$

$$\rho = \frac{A_s}{\phi bd} \le 0.02$$

$$\phi V_n = \phi 0.0316 b d F_{vp} \sqrt{f'c}\left(1.1 + 63\rho\right)\left(\frac{F_d F_n}{F_c}\right)$$

$$F_c = 1 \pm \left(\frac{d}{2 * rad}\right)$$

Shear Resistance Without Stirrups **AASHTO 12.10.4.2.5**

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3S2 Case 2

Technical Data & Load Factors

Culvert Span (S) =	28.00 ft.		
Crown Radius (Rad) =	33.82 ft.		
Bar Cover			
Outside Face (Cov_{out}) =	2.00 in		
Inside Face (Cov_{in}) =	1.50 in		
Design Section Length (b) =	12 in		
Compressive Strength (f_c) =	6.5 ksi		
Yield Strength (f_y) =	60 ksi		
Stirrup Yield Strength (f_{ystir}) =	60 ksi		
Circumferential Reinforcement Spa. (spa.) =	4.00 in		
Circumferential Reinforcement Provided (n) =	1	(n=1 for 1 layer, n=2 for multiple layers)	AASHTO
Reinforcement Type (Type) =	3	AASHTO Table	12.10.4.2.4d

1 - smooth wire or plain bar — 12.10.4.4d-1
2 - WWF (8" max spa. Smooth)
3 - WWF (deformed) or bar (deformed)

Resistance Factors:

ϕf - Flexure =	1.00	AASHTO Table 12.5.5-1
ϕr - Radial Tension =	0.90	
ϕv - Diag Tension =	0.90	
Radial Tension Process (F_{rp}) =	1.00	AASHTO 12.10.4.2.3
Diag Tension Process (F_{vp}) =	1.00	

Load Factors:

	IR	OR	
LL Factor		1.35	
$\gamma_p DC$ (component)	1.31		(1.25*1.05 = 1.3125)
$\gamma_p EH$ (hor. At rest earth pressure)	0.86		(0.9/1.05 = 0.857)
$\gamma_p EV$	1.37		(1.3*1.05 = 1.365)

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.		OF	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Design Force Summary LRFR LOAD RATING -3S2 Case 2

	Factored DC+EV+EH			Max Factored Total Load			Max Factored LL			
Node Number	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Thk at node (in)
1	-7.35	148.20	0.00	-14.12	239.44	0.01	-6.76	91.24	0.01	10.000
2	-7.40	145.37	0.42	-14.18	238.24	0.16	-6.78	92.87	-0.26	10.000
3	-7.47	136.94	0.84	-14.24	235.06	0.30	-6.77	98.11	-0.53	10.000
4	-7.59	122.94	1.26	-14.24	230.09	0.60	-6.65	107.15	-0.66	10.000
5	-7.78	103.28	1.68	-14.16	219.07	1.41	-6.38	115.79	-0.27	10.000
6	-8.03	77.90	2.12	-14.24	192.38	2.82	-6.21	114.48	0.70	10.000
7	-8.35	46.57	2.57	-14.69	143.59	4.60	-6.35	97.02	2.02	10.063
8	-8.71	8.90	3.07	-15.68	69.16	6.69	-6.97	60.26	3.62	10.063
9	-9.13	-35.60	3.61	-16.81	-35.72	8.47	-7.68	-0.12	4.87	10.063
10	-9.60	-87.80	4.24	-17.94	-157.91	10.04	-8.34	-70.11	5.80	10.625
11	-10.09	-149.20	4.99	-19.02	-304.81	11.29	-8.93	-155.62	6.30	12.313
12	-10.63	-221.57	5.88	-19.95	-460.57	12.03	-9.32	-239.00	6.14	15.125
13	-11.22	-306.83	6.94	-20.98	-627.11	12.91	-9.76	-320.28	5.97	19.125
14	-13.21	-407.64	1.78	-23.63	-806.52	2.53	-10.42	-398.88	0.75	27.000
15	-15.00	-357.89	-4.27	-25.63	-701.86	-8.95	-10.63	-343.97	-4.67	18.313
16	-15.14	-300.25	-4.92	-25.36	-581.69	-10.07	-10.22	-281.44	-5.14	13.563
17	-15.27	-234.07	-5.19	-25.13	-448.68	-10.22	-9.85	-214.61	-5.02	12.000
18	-15.50	-147.08	-4.81	-25.02	-281.36	-9.18	-9.52	-134.28	-4.37	12.000
19	-15.78	-70.81	-4.33	-25.02	-136.93	-8.29	-9.24	-66.13	-3.95	12.000
20	-16.07	0.00	-4.01	-25.12	0.00	-7.84	-9.05	0.00	-3.83	12.000

Note: "-" thrust indicate compression

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2014.059.004
DESCRIPTION 28x10 Arch
SHEET NO. OF SCALE
CALCULATED BY YL DATE 11/25/2014
CHECKED BY DATE

LRFR LOAD RATING -3S2 Case 2

Node	Total Fac.	Factored DC+EH+EV			Factored LL			
Number	Nu (k/ft)	Nu_D (k/ft)	Mu_D (in-k/ft)	Vu_D (k/ft)	Nu_{LL} (k/ft)	$+Mu_{LL}$ (in-k/ft)	Vu_{LL} (k/ft)	Thick (in)
1	-14.12	-7.35	148.20	0.00	-6.76	91.24	0.01	10
2	-14.18	-7.40	145.37	0.42	-6.78	92.87	0.26	10
3	-14.24	-7.47	136.94	0.84	-6.77	98.11	0.53	10
4	-14.24	-7.59	122.94	1.26	-6.65	107.15	0.66	10
5	-14.16	-7.78	103.28	1.68	-6.38	115.79	0.27	10
6	-14.24	-8.03	77.90	2.12	-6.21	114.48	0.70	10
7	-14.69	-8.35	46.57	2.57	-6.35	97.02	2.02	10.063
8	-15.68	-8.71	8.90	3.07	-6.97	60.26	3.62	10.063
9	-16.81	-9.13	-35.60	3.61	-7.68	-0.12	4.87	10.063
10	-17.94	-9.60	-87.80	4.24	-8.34	-70.11	5.80	10.625
11	-19.02	-10.09	-149.20	4.99	-8.93	-155.62	6.30	12.313
12	-19.95	-10.63	-221.57	5.88	-9.32	-239.00	6.14	15.125
13	-20.98	-11.22	-306.83	6.94	-9.76	-320.28	5.97	19.125
14	-23.63	-13.21	-407.64	1.78	-10.42	-398.88	0.75	27
15	-25.63	-15.00	-357.89	4.27	-10.63	-343.97	4.67	18.313
16	-25.36	-15.14	-300.25	4.92	-10.22	-281.44	5.14	13.563
17	-25.13	-15.27	-234.07	5.19	-9.85	-214.61	5.02	12
18	-25.02	-15.50	-147.08	4.81	-9.52	-134.28	4.37	12
19	-25.02	-15.78	-70.81	4.33	-9.24	-66.13	3.95	12
20	-25.12	-16.07	0.00	4.01	-9.05	0.00	3.83	12

note all shear values normalized to positive

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2014.059.004
DESCRIPTION 28x10 Arch
SHEET NO. OF SCALE
CALCULATED BY YL DATE 11/25/2014
CHECKED BY DATE

Node Number	thk (in)	d (in)	As'in (prov'd) (in^2 / ft)	As'out (prov'd) (in^2 / ft)
1	10.0	8.13	2.38	0.90
2	10.0	8.13	2.38	0.90
3	10.0	8.13	2.38	0.90
4	10.0	8.13	2.38	0.90
5	10.0	8.13	2.38	0.90
6	10.0	8.13	2.38	0.90
7	10.1	8.19	2.38	0.90
8	10.1	8.19	2.38	0.90
9	10.1	7.69	1.32	1.80
10	10.6	8.25	1.32	1.80
11	12.3	9.94	1.32	1.80
12	15.1	12.75	1.32	1.80
13	19.1	16.75	1.32	1.80
14	27.0	24.63	1.32	1.80
15	18.3	15.94	1.32	1.80
16	13.6	11.19	1.32	1.80
17	12.0	9.63	1.32	1.80
18	12.0	9.63	0.60	1.80
19	12.0	9.63	0.60	1.80
20	12.0	9.63	0.60	1.80

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3S2 Case 2

Node Number	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Total Fac. Nu (k/ft)	Phi Mn (in-k/ft)
1	10.0	8.13	2.38	-14.12	1043.76
2	10.0	8.13	2.38	-14.18	1043.92
3	10.0	8.13	2.38	-14.24	1044.07
4	10.0	8.13	2.38	-14.24	1044.08
5	10.0	8.13	2.38	-14.16	1043.88
6	10.0	8.13	2.38	-14.24	1044.07
7	10.1	8.19	2.38	-14.69	1054.72
8	10.1	8.19	2.38	-15.68	1057.34
9	10.1	7.69	1.80	-16.81	797.42
10	10.6	8.25	1.80	-17.94	866.69
11	12.3	9.94	1.80	-19.02	1068.73
12	15.1	12.75	1.80	-19.95	1404.40
13	19.1	16.75	1.80	-20.98	1884.19
14	27.0	24.63	1.80	-23.63	2847.87
15	18.3	15.94	1.80	-25.63	1821.33
16	13.6	11.19	1.80	-25.36	1246.15
17	12.0	9.63	1.80	-25.13	1056.60
18	12.0	9.63	1.80	-25.02	1056.17
19	12.0	9.63	1.80	-25.02	1056.18
20	12.0	9.63	1.80	-25.12	1056.59

AASHTO 12.10.4.2.4a

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3S2 Case 2

Node Number	thk (in)	d (in)	Phi Mn (in-k/ft)	Mu_D (in-k/ft)	$+Mu_{LL}$ (in-k/ft)		Operating Rating
1	10.0	8.13	1043.76	148.20	91.24		12.72
2	10.0	8.13	1043.92	145.37	92.87		12.54
3	10.0	8.13	1044.07	136.94	98.11		11.99
4	10.0	8.13	1044.08	122.94	107.15		11.14
5	10.0	8.13	1043.88	103.28	115.79		10.53
6	10.0	8.13	1044.07	77.90	114.48		10.94
7	10.1	8.19	1054.72	46.57	97.02		13.47
8	10.1	8.19	1057.34	8.90	60.26		22.55
9	10.1	7.69	797.42	-35.60	-0.12		8148.10
10	10.6	8.25	866.69	-87.80	-70.11		14.40
11	12.3	9.94	1068.73	-149.20	-155.62		7.66
12	15.1	12.75	1404.40	-221.57	-239.00		6.42
13	19.1	16.75	1884.19	-306.83	-320.28		6.38
14	27.0	24.63	2847.87	-407.64	-398.88		7.93
15	18.3	15.94	1821.33	-357.89	-343.97		5.52
16	13.6	11.19	1246.15	-300.25	-281.44		4.36
17	12.0	9.63	1056.60	-234.07	-214.61		4.97
18	12.0	9.63	1056.17	-147.08	-134.28		8.78
19	12.0	9.63	1056.18	-70.81	-66.13		19.32
20	12.0	9.63	1056.59	0.00	0.00		N/A
					Controlling		**4.36**

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA ENGINEERS
184 Court Street
BINGHAMTON, NEW YORK 13901
(607) 231-6600 Fax 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3S2 Case 2

Elmt Nmbr	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Vtotal (kip/ft)	Vdl only (kip/ft)	Vll only (kip/ft)	ϕVn (kip/ft)		1.35 OPR
1	10.0	8.125	2.38	0.01	0.00	0.01	19.16		1990
2	10.0	8.125	2.38	0.16	0.42	0.26	19.16		94.75
3	10.0	8.125	2.38	0.30	0.84	0.53	19.17		44.59
4	10.0	8.125	2.38	0.60	1.26	0.66	19.17		35.18
5	10.0	8.125	2.38	1.41	1.68	0.27	19.16		82.79
6	10.0	8.125	2.38	2.82	2.12	0.70	19.17		31.55
7	10.1	8.188	2.38	4.60	2.57	2.02	19.22		10.67
8	10.1	8.188	2.38	6.69	3.07	3.62	31.57		10.19
9	10.1	7.688	1.80	8.47	3.61	4.87	29.86		6.994
10	10.6	8.250	1.80	10.04	4.24	5.80	26.40		4.951
11	12.3	9.938	1.80	11.29	4.99	6.30	21.14		3.32
12	15.1	12.750	1.80	12.03	5.88	6.14	21.40		3.275
13	19.1	16.750	1.80	12.91	6.94	5.97	25.11		3.948
14	27.0	24.625	1.80	2.53	1.78	0.75	30.61		50.03
15	18.3	15.938	1.80	8.95	4.27	4.67	23.39		5.303
16	13.6	11.188	1.80	10.07	4.92	5.14	19.83		3.756
17	12.0	9.625	1.80	10.22	5.19	5.02	18.79		3.509
18	12.0	9.625	1.80	9.18	4.81	4.37	19.48		4.348
19	12.0	9.625	1.80	8.29	4.33	3.95	32.06		9.091
20	12.0	9.625	1.80	7.84	4.01	3.83	39.15		11.88
								controling:	**3.275**

$$F_d = 0.8 + \frac{1.6}{d} \le 1.3$$

$$F_n = 1 + \frac{N_u}{24 * thk}$$

$$\rho = \frac{A_s}{\phi bd} \le 0.02$$

$$\phi V_n = \phi 0.0316 b d F_{vp} \sqrt{f'c}\left(1.1 + 63\rho\right)\left(\frac{F_d F_n}{F_c}\right)$$

$$F_c = 1 \pm \left(\frac{d}{2 * rad}\right)$$

Shear Resistance Without Stirrups **AASHTO 12.10.4.2.5**

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -6 Axle Case 1

Technical Data & Load Factors

Culvert Span (S) =	28.00 ft.		
Crown Radius (Rad) =	33.82 ft.		
Bar Cover			
Outside Face (Cov_{out}) =	2.00 in		
Inside Face (Cov_{in}) =	1.50 in		
Design Section Length (b) =	12 in		
Compressive Strength (f_c) =	6.5 ksi		
Yield Strength (f_y) =	60 ksi		
Stirrup Yield Strength (f_{ystir}) =	60 ksi		
Circumferential Reinforcement Spa. (spa.) =	4.00 in		
Circumferential Reinforcement Provided (n) =	1	(n=1 for 1 layer, n=2 for multiple layers)	AASHTO
Reinforcement Type (Type) =	3	AASHTO Table	12.10.4.2.4d

1 - smooth wire or plain bar — 12.10.4.4d-1
2 - WWF (8" max spa. Smooth)
3 - WWF (deformed) or bar (deformed)

Resistance Factors:

ϕf - Flexure =	1.00	AASHTO Table 12.5.5-1
ϕr - Radial Tension =	0.90	
ϕv - Diag Tension =	0.90	
Radial Tension Process (F_{rp}) =	1.00	AASHTO 12.10.4.2.3
Diag Tension Process (F_{vp}) =	1.00	

Load Factors:

	IR	OR	
LL Factor		1.35	
γ_pDC (component)	1.31		(1.25*1.05 = 1.3125)
γ_pEH (hor. At rest earth pressure)	0.86		(0.9/1.05 = 0.857)
γ_pEV	1.37		(1.3*1.05 = 1.365)

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.		OF	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Design Force Summary LRFR LOAD RATING -6 Axle Case 1

	Factored DC+EV+EH			Max Factored Total Load			Max Factored LL			
Node Number	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Thk at node (in)
1	-7.35	148.20	0.00	-15.59	522.67	0.66	-8.24	374.47	0.66	10.000
2	-7.40	145.37	0.42	-16.42	503.54	2.19	-9.02	358.18	1.77	10.000
3	-7.47	136.94	0.84	-17.10	464.06	3.52	-9.62	327.12	2.69	10.000
4	-7.59	122.94	1.26	-17.39	409.13	5.22	-9.80	286.19	3.97	10.000
5	-7.78	103.28	1.68	-18.03	324.08	7.36	-10.26	220.80	5.68	10.000
6	-8.03	77.90	2.12	-19.22	211.94	9.17	-11.19	134.04	7.06	10.000
7	-8.35	46.57	2.57	-20.30	78.24	10.52	-11.96	31.66	7.95	10.063
8	-8.71	8.90	3.07	-21.07	-69.99	10.95	-12.35	-78.89	7.89	10.063
9	-9.13	-35.60	3.61	-21.67	-215.28	10.91	-12.54	-179.68	7.30	10.063
10	-9.60	-87.80	4.24	-22.39	-362.42	11.12	-12.79	-274.62	6.88	10.625
11	-10.09	-149.20	4.99	-23.19	-513.19	11.47	-13.10	-364.00	6.48	12.313
12	-10.63	-221.57	5.88	-24.09	-669.89	12.00	-13.46	-448.32	6.12	15.125
13	-11.22	-306.83	6.94	-25.12	-834.74	12.77	-13.90	-527.92	5.82	19.125
14	-13.21	-407.64	1.78	-26.78	-1011.98	0.94	-13.57	-604.34	-0.84	27.000
15	-15.00	-357.89	-4.27	-27.64	-869.44	-11.87	-12.64	-511.55	-7.60	18.313
16	-15.14	-300.25	-4.92	-27.09	-713.65	-12.77	-11.95	-413.40	-7.84	13.563
17	-15.27	-234.07	-5.19	-26.61	-548.40	-12.60	-11.34	-314.33	-7.40	12.000
18	-15.50	-147.08	-4.81	-26.27	-343.85	-11.22	-10.77	-196.76	-6.41	12.000
19	-15.78	-70.81	-4.33	-26.13	-167.40	-10.13	-10.35	-96.59	-5.79	12.000
20	-16.07	0.00	-4.01	-26.19	0.00	-9.59	-10.12	0.00	-5.58	12.000

Note: "-" thrust indicate compression

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -6 Axle Case 1

Node	Total Fac.	Factored DC+EH+EV			Factored LL			
Number	Nu (k/ft)	Nu_D (k/ft)	Mu_D (in-k/ft)	Vu_D (k/ft)	Nu_{LL} (k/ft)	$+Mu_{LL}$ (in-k/ft)	Vu_{LL} (k/ft)	Thick (in)
1	-15.59	-7.35	148.20	0.00	-8.24	374.47	0.66	10
2	-16.42	-7.40	145.37	0.42	-9.02	358.18	1.77	10
3	-17.10	-7.47	136.94	0.84	-9.62	327.12	2.69	10
4	-17.39	-7.59	122.94	1.26	-9.80	286.19	3.97	10
5	-18.03	-7.78	103.28	1.68	-10.26	220.80	5.68	10
6	-19.22	-8.03	77.90	2.12	-11.19	134.04	7.06	10
7	-20.30	-8.35	46.57	2.57	-11.96	31.66	7.95	10.063
8	-21.07	-8.71	8.90	3.07	-12.35	-78.89	7.89	10.063
9	-21.67	-9.13	-35.60	3.61	-12.54	-179.68	7.30	10.063
10	-22.39	-9.60	-87.80	4.24	-12.79	-274.62	6.88	10.625
11	-23.19	-10.09	-149.20	4.99	-13.10	-364.00	6.48	12.313
12	-24.09	-10.63	-221.57	5.88	-13.46	-448.32	6.12	15.125
13	-25.12	-11.22	-306.83	6.94	-13.90	-527.92	5.82	19.125
14	-26.78	-13.21	-407.64	1.78	-13.57	-604.34	0.84	27
15	-27.64	-15.00	-357.89	4.27	-12.64	-511.55	7.60	18.313
16	-27.09	-15.14	-300.25	4.92	-11.95	-413.40	7.84	13.563
17	-26.61	-15.27	-234.07	5.19	-11.34	-314.33	7.40	12
18	-26.27	-15.50	-147.08	4.81	-10.77	-196.76	6.41	12
19	-26.13	-15.78	-70.81	4.33	-10.35	-96.59	5.79	12
20	-26.19	-16.07	0.00	4.01	-10.12	0.00	5.58	12

note all shear values normalized to positive

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2014.059.004
DESCRIPTION 28x10 Arch
SHEET NO. OF SCALE
CALCULATED BY YL DATE 11/25/2014
CHECKED BY DATE

Node Number	thk (in)	d (in)	As'in (prov'd) (in^2 / ft)	As'out (prov'd) (in^2 / ft)
1	10.0	8.13	2.38	0.90
2	10.0	8.13	2.38	0.90
3	10.0	8.13	2.38	0.90
4	10.0	8.13	2.38	0.90
5	10.0	8.13	2.38	0.90
6	10.0	8.13	2.38	0.90
7	10.1	8.19	2.38	0.90
8	10.1	7.69	2.38	0.90
9	10.1	7.69	1.32	1.80
10	10.6	8.25	1.32	1.80
11	12.3	9.94	1.32	1.80
12	15.1	12.75	1.32	1.80
13	19.1	16.75	1.32	1.80
14	27.0	24.63	1.32	1.80
15	18.3	15.94	1.32	1.80
16	13.6	11.19	1.32	1.80
17	12.0	9.63	1.32	1.80
18	12.0	9.63	0.60	1.80
19	12.0	9.63	0.60	1.80
20	12.0	9.63	0.60	1.80

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -6 Axle Case 1

Node Number	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Total Fac. Nu (k/ft)	Phi Mn (in-k/ft)
1	10.0	8.13	2.38	-15.59	1047.62
2	10.0	8.13	2.38	-16.42	1049.79
3	10.0	8.13	2.38	-17.10	1051.55
4	10.0	8.13	2.38	-17.39	1052.32
5	10.0	8.13	2.38	-18.03	1053.97
6	10.0	8.13	2.38	-19.22	1057.01
7	10.1	8.19	2.38	-20.30	1069.40
8	10.1	7.69	0.90	-21.07	478.66
9	10.1	7.69	1.80	-21.67	812.53
10	10.6	8.25	1.80	-22.39	881.72
11	12.3	9.94	1.80	-23.19	1086.26
12	15.1	12.75	1.80	-24.09	1427.59
13	19.1	16.75	1.80	-25.12	1915.59
14	27.0	24.63	1.80	-26.78	2884.04
15	18.3	15.94	1.80	-27.64	1835.63
16	13.6	11.19	1.80	-27.09	1254.38
17	12.0	9.63	1.80	-26.61	1062.51
18	12.0	9.63	1.80	-26.27	1061.16
19	12.0	9.63	1.80	-26.13	1060.59
20	12.0	9.63	1.80	-26.19	1060.85

AASHTO 12.10.4.2.4a

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -6 Axle Case 1

Node Number	thk (in)	d (in)	Phi Mn (in-k/ft)	Mu_D (in-k/ft)	$+Mu_{LL}$ (in-k/ft)		Operating Rating
1	10.0	8.13	1047.62	148.20	374.47		3.11
2	10.0	8.13	1049.79	145.37	358.18		3.27
3	10.0	8.13	1051.55	136.94	327.12		3.62
4	10.0	8.13	1052.32	122.94	286.19		4.21
5	10.0	8.13	1053.97	103.28	220.80		5.58
6	10.0	8.13	1057.01	77.90	134.04		9.47
7	10.1	8.19	1069.40	46.57	31.66		41.87
8	10.1	7.69	478.66	8.90	-78.89		8.01
9	10.1	7.69	812.53	-35.60	-179.68		5.61
10	10.6	8.25	881.72	-87.80	-274.62		3.75
11	12.3	9.94	1086.26	-149.20	-364.00		3.34
12	15.1	12.75	1427.59	-221.57	-448.32		3.49
13	19.1	16.75	1915.59	-306.83	-527.92		3.95
14	27.0	24.63	2884.04	-407.64	-604.34		5.31
15	18.3	15.94	1835.63	-357.89	-511.55		3.74
16	13.6	11.19	1254.38	-300.25	-413.40		2.99
17	12.0	9.63	1062.51	-234.07	-314.33		3.42
18	12.0	9.63	1061.16	-147.08	-196.76		6.02
19	12.0	9.63	1060.59	-70.81	-96.59		13.28
20	12.0	9.63	1060.85	0.00	0.00		N/A
					Controlling		**2.99**

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA ENGINEERS
184 Court Street
BINGHAMTON, NEW YORK 13901
(607) 231-6600 Fax 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -6 Axle Case 1

Elmt Nmbr	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Vtotal (kip/ft)	Vdl only (kip/ft)	Vll only (kip/ft)	ϕVn (kip/ft)		1.35 OPR
1	10.0	8.125	2.38	0.66	0.00	0.66	19.27		37.69
2	10.0	8.125	2.38	2.19	0.42	1.77	19.33		13.88
3	10.0	8.125	2.38	3.52	0.84	2.69	19.38		8.95
4	10.0	8.125	2.38	5.22	1.26	3.97	19.41		5.93
5	10.0	8.125	2.38	7.36	1.68	5.68	19.45		4.058
6	10.0	8.125	2.38	9.17	2.12	7.06	21.56		3.571
7	10.1	8.188	2.38	10.52	2.57	7.95	31.57		4.73
8	10.1	7.688	0.90	10.95	3.07	7.89	29.86		4.403
9	10.1	7.688	1.80	10.91	3.61	7.30	21.36		3.151
10	10.6	8.250	1.80	11.12	4.24	6.88	17.81		2.557
11	12.3	9.938	1.80	11.47	4.99	6.48	18.87		2.776
12	15.1	12.750	1.80	12.00	5.88	6.12	20.87		3.177
13	19.1	16.750	1.80	12.77	6.94	5.82	24.01		3.8
14	27.0	24.625	1.80	0.94	1.78	0.84	30.76		44.59
15	18.3	15.938	1.80	11.87	4.27	7.60	23.49		3.279
16	13.6	11.188	1.80	12.77	4.92	7.84	19.93		2.48
17	12.0	9.625	1.80	12.60	5.19	7.40	18.88		2.396
18	12.0	9.625	1.80	11.22	4.81	6.41	19.31		2.932
19	12.0	9.625	1.80	10.13	4.33	5.79	31.42		6.06
20	12.0	9.625	1.80	9.59	4.01	5.58	39.15		8.159
								controling:	**2.396**

$$F_d = 0.8 + \frac{1.6}{d} \le 1.3$$

$$F_n = 1 + \frac{N_u}{24 * thk}$$

$$\rho = \frac{A_s}{\phi bd} \le 0.02$$

$$\phi V_n = \phi 0.0316 b d F_{vp} \sqrt{f'c}\left(1.1 + 63\rho\right)\left(\frac{F_d F_n}{F_c}\right)$$

$$F_c = 1 \pm \left(\frac{d}{2 * rad}\right)$$

Shear Resistance Without Stirrups **AASHTO 12.10.4.2.5**

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -6 Axle Case 2

Technical Data & Load Factors

Culvert Span (S) =	28.00 ft.		
Crown Radius (Rad) =	33.82 ft.		
Bar Cover			
Outside Face (Cov_{out}) =	2.00 in		
Inside Face (Cov_{in}) =	1.50 in		
Design Section Length (b) =	12 in		
Compressive Strength (f_c) =	6.5 ksi		
Yield Strength (f_y) =	60 ksi		
Stirrup Yield Strength (f_{ystir}) =	60 ksi		
Circumferential Reinforcement Spa. (spa.) =	4.00 in		
Circumferential Reinforcement Provided (n) =	1	(n=1 for 1 layer, n=2 for multiple layers)	AASHTO
Reinforcement Type (Type) =	3	AASHTO Table	12.10.4.2.4d
1 - smooth wire or plain bar		12.10.4.4d-1	
2 - WWF (8" max spa. Smooth)			
3 - WWF (deformed) or bar (deformed)			

Resistance Factors:

ϕf - Flexure =	1.00	AASHTO Table 12.5.5-1
ϕr - Radial Tension =	0.90	
ϕv - Diag Tension =	0.90	
Radial Tension Process (F_{rp}) =	1.00	AASHTO 12.10.4.2.3
Diag Tension Process (F_{vp}) =	1.00	

Load Factors:

	IR	OR	
LL Factor		1.35	
γ_pDC (component)	1.31		(1.25*1.05 = 1.3125)
γ_pEH (hor. At rest earth pressure)	0.86		(0.9/1.05 = 0.857)
γ_pEV	1.37		(1.3*1.05 = 1.365)

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.		OF	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Design Force Summary LRFR LOAD RATING -6 Axle Case 2

	Factored DC+EV+EH			Max Factored Total Load			Max Factored LL			
Node Number	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Thk at node (in)
1	-7.35	148.20	0.00	-22.20	393.66	-0.04	-14.85	245.46	-0.04	10.000
2	-7.40	145.37	0.42	-22.09	394.90	-0.15	-14.69	249.53	-0.57	10.000
3	-7.47	136.94	0.84	-21.84	397.64	0.07	-14.37	260.70	-0.77	10.000
4	-7.59	122.94	1.26	-21.45	393.05	1.24	-13.86	270.11	-0.01	10.000
5	-7.78	103.28	1.68	-21.44	364.37	3.19	-13.67	261.08	1.51	10.000
6	-8.03	77.90	2.12	-22.07	307.56	5.46	-14.04	229.66	3.34	10.000
7	-8.35	46.57	2.57	-23.33	218.08	8.16	-14.99	171.50	5.59	10.063
8	-8.71	8.90	3.07	-24.57	88.84	10.56	-15.85	79.94	7.49	10.063
9	-9.13	-35.60	3.61	-26.05	-64.91	13.24	-16.92	-29.32	9.64	10.063
10	-9.60	-87.80	4.24	-27.71	-266.09	15.66	-18.11	-178.29	11.42	10.625
11	-10.09	-149.20	4.99	-29.31	-484.60	17.67	-19.22	-335.40	12.68	12.313
12	-10.63	-221.57	5.88	-31.02	-739.52	19.44	-20.39	-517.96	13.56	15.125
13	-11.22	-306.83	6.94	-32.44	-1005.50	20.30	-21.22	-698.68	13.36	19.125
14	-13.21	-407.64	1.78	-36.06	-1283.64	3.75	-22.85	-876.00	1.97	27.000
15	-15.00	-357.89	-4.27	-38.61	-1117.09	-14.23	-23.61	-759.20	-9.95	18.313
16	-15.14	-300.25	-4.92	-37.81	-926.04	-15.94	-22.68	-625.79	-11.02	13.563
17	-15.27	-234.07	-5.19	-37.11	-716.30	-16.17	-21.84	-482.23	-10.98	12.000
18	-15.50	-147.08	-4.81	-36.65	-450.37	-14.63	-21.15	-303.29	-9.82	12.000
19	-15.78	-70.81	-4.33	-36.44	-219.47	-13.26	-20.66	-148.66	-8.93	12.000
20	-16.07	0.00	-4.01	-36.45	0.00	-12.59	-20.38	0.00	-8.58	12.000

Note: "-" thrust indicate compression

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -6 Axle Case 2

Node	Total Fac.	Factored DC+EH+EV			Factored LL			
Number	Nu (k/ft)	Nu_D (k/ft)	Mu_D (in-k/ft)	Vu_D (k/ft)	Nu_{LL} (k/ft)	$+Mu_{LL}$ (in-k/ft)	Vu_{LL} (k/ft)	Thick (in)
1	-22.20	-7.35	148.20	0.00	-14.85	245.46	0.04	10
2	-22.09	-7.40	145.37	0.42	-14.69	249.53	0.57	10
3	-21.84	-7.47	136.94	0.84	-14.37	260.70	0.77	10
4	-21.45	-7.59	122.94	1.26	-13.86	270.11	0.01	10
5	-21.44	-7.78	103.28	1.68	-13.67	261.08	1.51	10
6	-22.07	-8.03	77.90	2.12	-14.04	229.66	3.34	10
7	-23.33	-8.35	46.57	2.57	-14.99	171.50	5.59	10.063
8	-24.57	-8.71	8.90	3.07	-15.85	79.94	7.49	10.063
9	-26.05	-9.13	-35.60	3.61	-16.92	-29.32	9.64	10.063
10	-27.71	-9.60	-87.80	4.24	-18.11	-178.29	11.42	10.625
11	-29.31	-10.09	-149.20	4.99	-19.22	-335.40	12.68	12.313
12	-31.02	-10.63	-221.57	5.88	-20.39	-517.96	13.56	15.125
13	-32.44	-11.22	-306.83	6.94	-21.22	-698.68	13.36	19.125
14	-36.06	-13.21	-407.64	1.78	-22.85	-876.00	1.97	27
15	-38.61	-15.00	-357.89	4.27	-23.61	-759.20	9.95	18.313
16	-37.81	-15.14	-300.25	4.92	-22.68	-625.79	11.02	13.563
17	-37.11	-15.27	-234.07	5.19	-21.84	-482.23	10.98	12
18	-36.65	-15.50	-147.08	4.81	-21.15	-303.29	9.82	12
19	-36.44	-15.78	-70.81	4.33	-20.66	-148.66	8.93	12
20	-36.45	-16.07	0.00	4.01	-20.38	0.00	8.58	12

note all shear values normalized to positive

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Node Number	thk (in)	d (in)	As'in (prov'd) (in^2 / ft)	As'out (prov'd) (in^2 / ft)
1	10.0	8.13	2.38	0.90
2	10.0	8.13	2.38	0.90
3	10.0	8.13	2.38	0.90
4	10.0	8.13	2.38	0.90
5	10.0	8.13	2.38	0.90
6	10.0	8.13	2.38	0.90
7	10.1	8.19	2.38	0.90
8	10.1	8.19	2.38	0.90
9	10.1	7.69	1.32	1.80
10	10.6	8.25	1.32	1.80
11	12.3	9.94	1.32	1.80
12	15.1	12.75	1.32	1.80
13	19.1	16.75	1.32	1.80
14	27.0	24.63	1.32	1.80
15	18.3	15.94	1.32	1.80
16	13.6	11.19	1.32	1.80
17	12.0	9.63	1.32	1.80
18	12.0	9.63	0.60	1.80
19	12.0	9.63	0.60	1.80
20	12.0	9.63	0.60	1.80

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -6 Axle Case 2

Node Number	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Total Fac. Nu (k/ft)	Phi Mn (in-k/ft)
1	10.0	8.13	2.38	-22.20	1064.59
2	10.0	8.13	2.38	-22.09	1064.30
3	10.0	8.13	2.38	-21.84	1063.68
4	10.0	8.13	2.38	-21.45	1062.70
5	10.0	8.13	2.38	-21.44	1062.67
6	10.0	8.13	2.38	-22.07	1064.24
7	10.1	8.19	2.38	-23.33	1077.14
8	10.1	8.19	2.38	-24.57	1080.24
9	10.1	7.69	1.80	-26.05	825.86
10	10.6	8.25	1.80	-27.71	899.32
11	12.3	9.94	1.80	-29.31	1111.56
12	15.1	12.75	1.80	-31.02	1465.83
13	19.1	16.75	1.80	-32.44	1970.46
14	27.0	24.63	1.80	-36.06	2989.85
15	18.3	15.94	1.80	-38.61	1912.75
16	13.6	11.19	1.80	-37.81	1304.40
17	12.0	9.63	1.80	-37.11	1103.37
18	12.0	9.63	1.80	-36.65	1101.62
19	12.0	9.63	1.80	-36.44	1100.82
20	12.0	9.63	1.80	-36.45	1100.85

AASHTO 12.10.4.2.4a

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -6 Axle Case 2

Node Number	thk (in)	d (in)	Phi Mn (in-k/ft)	Mu_D (in-k/ft)	$+Mu_{LL}$ (in-k/ft)		Operating Rating
1	10.0	8.13	1064.59	148.20	245.46		4.84
2	10.0	8.13	1064.30	145.37	249.53		4.77
3	10.0	8.13	1063.68	136.94	260.70		4.61
4	10.0	8.13	1062.70	122.94	270.11		4.51
5	10.0	8.13	1062.67	103.28	261.08		4.76
6	10.0	8.13	1064.24	77.90	229.66		5.57
7	10.1	8.19	1077.14	46.57	171.50		7.79
8	10.1	8.19	1080.24	8.90	79.94		17.37
9	10.1	7.69	825.86	-35.60	-29.32		34.94
10	10.6	8.25	899.32	-87.80	-178.29		5.90
11	12.3	9.94	1111.56	-149.20	-335.40		3.72
12	15.1	12.75	1465.83	-221.57	-517.96		3.11
13	19.1	16.75	1970.46	-306.83	-698.68		3.09
14	27.0	24.63	2989.85	-407.64	-876.00		3.82
15	18.3	15.94	1912.75	-357.89	-759.20		2.65
16	13.6	11.19	1304.40	-300.25	-625.79		2.08
17	12.0	9.63	1103.37	-234.07	-482.23		2.34
18	12.0	9.63	1101.62	-147.08	-303.29		4.08
19	12.0	9.63	1100.82	-70.81	-148.66		8.98
20	12.0	9.63	1100.85	0.00	0.00		N/A
					Controlling		**2.08**

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA ENGINEERS
184 Court Street
BINGHAMTON, NEW YORK 13901
(607) 231-6600 Fax 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -6 Axle Case 2

Elmt Nmbr	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Vtotal (kip/ft)	Vdl only (kip/ft)	Vll only (kip/ft)	ϕVn (kip/ft)		1.35 OPR
1	10.0	8.125	2.38	0.04	0.00	0.04	19.77		682.2
2	10.0	8.125	2.38	0.15	0.42	0.57	19.76		44.1
3	10.0	8.125	2.38	0.07	0.84	0.77	19.74		31.89
4	10.0	8.125	2.38	1.24	1.26	0.01	19.71		1634
5	10.0	8.125	2.38	3.19	1.68	1.51	19.71		15.48
6	10.0	8.125	2.38	5.46	2.12	3.34	19.76		6.841
7	10.1	8.188	2.38	8.16	2.57	5.59	20.08		4.061
8	10.1	8.188	2.38	10.56	3.07	7.49	31.57		4.931
9	10.1	7.688	1.80	13.24	3.61	9.64	29.86		3.531
10	10.6	8.250	1.80	15.66	4.24	11.42	25.82		2.449
11	12.3	9.938	1.80	17.67	4.99	12.68	21.54		1.692
12	15.1	12.750	1.80	19.44	5.88	13.56	22.10		1.551
13	19.1	16.750	1.80	20.30	6.94	13.36	25.32		1.783
14	27.0	24.625	1.80	3.75	1.78	1.97	31.18		19.37
15	18.3	15.938	1.80	14.23	4.27	9.95	24.04		2.575
16	13.6	11.188	1.80	15.94	4.92	11.02	20.54		1.837
17	12.0	9.625	1.80	16.17	5.19	10.98	19.51		1.69
18	12.0	9.625	1.80	14.63	4.81	9.82	19.98		2.002
19	12.0	9.625	1.80	13.26	4.33	8.93	32.72		4.12
20	12.0	9.625	1.80	12.59	4.01	8.58	39.15		5.31
								controling:	**1.551**

$$F_d = 0.8 + \frac{1.6}{d} \le 1.3$$

$$F_n = 1 + \frac{N_u}{24 * thk}$$

$$\rho = \frac{A_s}{\phi bd} \le 0.02$$

$$\phi V_n = \phi 0.0316 b d F_{vp} \sqrt{f'c}\left(1.1 + 63\rho\right)\left(\frac{F_d F_n}{F_c}\right)$$

$$F_c = 1 \pm \left(\frac{d}{2 * rad}\right)$$

Shear Resistance Without Stirrups **AASHTO 12.10.4.2.5**

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3 Axle Case 1

Technical Data & Load Factors

Culvert Span (S) =	28.00 ft.		
Crown Radius (Rad) =	33.82 ft.		
Bar Cover			
Outside Face (Cov_{out}) =	2.00 in		
Inside Face (Cov_{in}) =	1.50 in		
Design Section Length (b) =	12 in		
Compressive Strength (f_c) =	6.5 ksi		
Yield Strength (f_y) =	60 ksi		
Stirrup Yield Strength (f_{ystir}) =	60 ksi		
Circumferential Reinforcement Spa. (spa.) =	4.00 in		
Circumferential Reinforcement Provided (n) =	1	(n=1 for 1 layer, n=2 for multiple layers)	AASHTO
Reinforcement Type (Type) =	3	AASHTO Table	12.10.4.2.4d
1 - smooth wire or plain bar		12.10.4.4d-1	
2 - WWF (8" max spa. Smooth)			
3 - WWF (deformed) or bar (deformed)			

Resistance Factors:

ϕf - Flexure =	1.00	AASHTO Table 12.5.5-1
ϕr - Radial Tension =	0.90	AASHTO Table 12.5.5-1
ϕv - Diag Tension =	0.90	AASHTO Table 12.5.5-1
Radial Tension Process (F_{rp}) =	1.00	AASHTO 12.10.4.2.3
Diag Tension Process (F_{vp}) =	1.00	AASHTO 12.10.4.2.3

Load Factors:

	IR	OR	
LL Factor		1.35	
γ_pDC (component)	1.31		(1.25*1.05 = 1.3125)
γ_pEH (hor. At rest earth pressure)	0.86		(0.9/1.05 = 0.857)
γ_pEV	1.37		(1.3*1.05 = 1.365)

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.		OF	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Design Force Summary LRFR LOAD RATING -3 Axle Case 1

	Factored DC+EV+EH			Max Factored Total Load			Max Factored LL			
Node Number	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Thk at node (in)
1	-7.35	148.20	0.00	-13.65	512.58	-0.23	-6.30	364.38	-0.23	10.000
2	-7.40	145.37	0.42	-13.85	493.96	3.00	-6.46	348.59	2.58	10.000
3	-7.47	136.94	0.84	-14.52	432.06	5.64	-7.05	295.12	4.80	10.000
4	-7.59	122.94	1.26	-15.51	342.90	7.23	-7.91	219.96	5.97	10.000
5	-7.78	103.28	1.68	-16.20	238.43	7.94	-8.43	135.14	6.26	10.000
6	-8.03	77.90	2.12	-16.64	130.08	7.95	-8.61	52.18	5.84	10.000
7	-8.35	46.57	2.57	-17.07	25.33	7.91	-8.72	-21.25	5.33	10.063
8	-8.71	8.90	3.07	-17.59	-81.76	8.05	-8.87	-90.66	4.99	10.063
9	-9.13	-35.60	3.61	-18.15	-190.49	8.26	-9.02	-154.89	4.65	10.063
10	-9.60	-87.80	4.24	-18.79	-303.02	8.61	-9.20	-215.22	4.37	10.625
11	-10.09	-149.20	4.99	-19.53	-421.32	9.12	-9.44	-272.12	4.13	12.313
12	-10.63	-221.57	5.88	-20.36	-547.43	9.80	-9.74	-325.86	3.91	15.125
13	-11.22	-306.83	6.94	-21.19	-683.83	10.69	-9.98	-377.00	3.75	19.125
14	-13.21	-407.64	1.78	-22.67	-833.95	0.92	-9.46	-426.31	-0.86	27.000
15	-15.00	-357.89	-4.27	-23.61	-716.39	-9.79	-8.61	-358.50	-5.51	18.313
16	-15.14	-300.25	-4.92	-23.25	-588.02	-10.54	-8.12	-287.77	-5.61	13.563
17	-15.27	-234.07	-5.19	-22.94	-451.48	-10.39	-7.67	-217.40	-5.20	12.000
18	-15.50	-147.08	-4.81	-22.73	-282.94	-9.24	-7.23	-135.85	-4.43	12.000
19	-15.78	-70.81	-4.33	-22.67	-137.63	-8.33	-6.89	-66.82	-4.00	12.000
20	-16.07	0.00	-4.01	-22.77	0.00	-7.88	-6.69	0.00	-3.87	12.000

Note: "-" thrust indicate compression

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3 Axle Case 1

Node	Total Fac.	Factored DC+EH+EV			Factored LL			
Number	Nu (k/ft)	Nu_D (k/ft)	Mu_D (in-k/ft)	Vu_D (k/ft)	Nu_{LL} (k/ft)	$+Mu_{LL}$ (in-k/ft)	Vu_{LL} (k/ft)	Thick (in)
1	-13.65	-7.35	148.20	0.00	-6.30	364.38	0.23	10
2	-13.85	-7.40	145.37	0.42	-6.46	348.59	2.58	10
3	-14.52	-7.47	136.94	0.84	-7.05	295.12	4.80	10
4	-15.51	-7.59	122.94	1.26	-7.91	219.96	5.97	10
5	-16.20	-7.78	103.28	1.68	-8.43	135.14	6.26	10
6	-16.64	-8.03	77.90	2.12	-8.61	52.18	5.84	10
7	-17.07	-8.35	46.57	2.57	-8.72	-21.25	5.33	10.063
8	-17.59	-8.71	8.90	3.07	-8.87	-90.66	4.99	10.063
9	-18.15	-9.13	-35.60	3.61	-9.02	-154.89	4.65	10.063
10	-18.79	-9.60	-87.80	4.24	-9.20	-215.22	4.37	10.625
11	-19.53	-10.09	-149.20	4.99	-9.44	-272.12	4.13	12.313
12	-20.36	-10.63	-221.57	5.88	-9.74	-325.86	3.91	15.125
13	-21.19	-11.22	-306.83	6.94	-9.98	-377.00	3.75	19.125
14	-22.67	-13.21	-407.64	1.78	-9.46	-426.31	0.86	27
15	-23.61	-15.00	-357.89	4.27	-8.61	-358.50	5.51	18.313
16	-23.25	-15.14	-300.25	4.92	-8.12	-287.77	5.61	13.563
17	-22.94	-15.27	-234.07	5.19	-7.67	-217.40	5.20	12
18	-22.73	-15.50	-147.08	4.81	-7.23	-135.85	4.43	12
19	-22.67	-15.78	-70.81	4.33	-6.89	-66.82	4.00	12
20	-22.77	-16.07	0.00	4.01	-6.69	0.00	3.87	12

note all shear values normalized to positive

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2014.059.004
DESCRIPTION 28x10 Arch
SHEET NO. OF SCALE
CALCULATED BY YL DATE 11/25/2014
CHECKED BY DATE

Node Number	thk (in)	d (in)	As'in (prov'd) (in^2 / ft)	As'out (prov'd) (in^2 / ft)
1	10.0	8.13	2.38	0.90
2	10.0	8.13	2.38	0.90
3	10.0	8.13	2.38	0.90
4	10.0	8.13	2.38	0.90
5	10.0	8.13	2.38	0.90
6	10.0	8.13	2.38	0.90
7	10.1	8.19	2.38	0.90
8	10.1	7.69	2.38	0.90
9	10.1	7.69	1.32	1.80
10	10.6	8.25	1.32	1.80
11	12.3	9.94	1.32	1.80
12	15.1	12.75	1.32	1.80
13	19.1	16.75	1.32	1.80
14	27.0	24.63	1.32	1.80
15	18.3	15.94	1.32	1.80
16	13.6	11.19	1.32	1.80
17	12.0	9.63	1.32	1.80
18	12.0	9.63	0.60	1.80
19	12.0	9.63	0.60	1.80
20	12.0	9.63	0.60	1.80

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3 Axle Case 1

Node Number	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Total Fac. Nu (k/ft)	Phi Mn (in-k/ft)
1	10.0	8.13	2.38	-13.65	1042.53
2	10.0	8.13	2.38	-13.85	1043.07
3	10.0	8.13	2.38	-14.52	1044.82
4	10.0	8.13	2.38	-15.51	1047.41
5	10.0	8.13	2.38	-16.20	1049.23
6	10.0	8.13	2.38	-16.64	1050.37
7	10.1	8.19	2.38	-17.07	1061.00
8	10.1	7.69	0.90	-17.59	464.99
9	10.1	7.69	1.80	-18.15	801.61
10	10.6	8.25	1.80	-18.79	869.60
11	12.3	9.94	1.80	-19.53	1070.87
12	15.1	12.75	1.80	-20.36	1406.73
13	19.1	16.75	1.80	-21.19	1885.80
14	27.0	24.63	1.80	-22.67	2836.80
15	18.3	15.94	1.80	-23.61	1806.88
16	13.6	11.19	1.80	-23.25	1236.08
17	12.0	9.63	1.80	-22.94	1047.86
18	12.0	9.63	1.80	-22.73	1047.00
19	12.0	9.63	1.80	-22.67	1046.74
20	12.0	9.63	1.80	-22.77	1047.14

AASHTO 12.10.4.2.4a

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3 Axle Case 1

Node Number	thk (in)	d (in)	Phi Mn (in-k/ft)	Mu_D (in-k/ft)	$+Mu_{LL}$ (in-k/ft)		Operating Rating
1	10.0	8.13	1042.53	148.20	364.38		3.18
2	10.0	8.13	1043.07	145.37	348.59		3.34
3	10.0	8.13	1044.82	136.94	295.12		3.99
4	10.0	8.13	1047.41	122.94	219.96		5.45
5	10.0	8.13	1049.23	103.28	135.14		9.07
6	10.0	8.13	1050.37	77.90	52.18		24.16
7	10.1	8.19	1061.00	46.57	-21.25		67.58
8	10.1	7.69	464.99	8.90	-90.66		6.78
9	10.1	7.69	801.61	-35.60	-154.89		6.41
10	10.6	8.25	869.60	-87.80	-215.22		4.71
11	12.3	9.94	1070.87	-149.20	-272.12		4.39
12	15.1	12.75	1406.73	-221.57	-325.86		4.71
13	19.1	16.75	1885.80	-306.83	-377.00		5.43
14	27.0	24.63	2836.80	-407.64	-426.31		7.39
15	18.3	15.94	1806.88	-357.89	-358.50		5.24
16	13.6	11.19	1236.08	-300.25	-287.77		4.22
17	12.0	9.63	1047.86	-234.07	-217.40		4.85
18	12.0	9.63	1047.00	-147.08	-135.85		8.59
19	12.0	9.63	1046.74	-70.81	-66.82		18.93
20	12.0	9.63	1047.14	0.00	0.00		N/A
					Controlling		**3.18**

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA ENGINEERS
184 Court Street
BINGHAMTON, NEW YORK 13901
(607) 231-6600 Fax 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3 Axle Case 1

Elmt Nmbr	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Vtotal (kip/ft)	Vdl only (kip/ft)	Vll only (kip/ft)	ϕVn (kip/ft)		1.35 OPR
1	10.0	8.125	2.38	0.23	0.00	0.23	19.12		108
2	10.0	8.125	2.38	3.00	0.42	2.58	19.14		9.39
3	10.0	8.125	2.38	5.64	0.84	4.80	19.19		4.956
4	10.0	8.125	2.38	7.23	1.26	5.97	19.26		3.911
5	10.0	8.125	2.38	7.94	1.68	6.26	19.32		3.651
6	10.0	8.125	2.38	7.95	2.12	5.84	27.81		5.707
7	10.1	8.188	2.38	7.91	2.57	5.33	31.57		7.051
8	10.1	7.688	0.90	8.05	3.07	4.99	25.50		5.831
9	10.1	7.688	1.80	8.26	3.61	4.65	18.76		4.224
10	10.6	8.250	1.80	8.61	4.24	4.37	17.58		3.952
11	12.3	9.938	1.80	9.12	4.99	4.13	18.66		4.291
12	15.1	12.750	1.80	9.80	5.88	3.91	20.67		4.899
13	19.1	16.750	1.80	10.69	6.94	3.75	23.82		5.835
14	27.0	24.625	1.80	0.92	1.78	0.86	30.57		43.42
15	18.3	15.938	1.80	9.79	4.27	5.51	23.29		4.472
16	13.6	11.188	1.80	10.54	4.92	5.61	19.71		3.416
17	12.0	9.625	1.80	10.39	5.19	5.20	18.66		3.356
18	12.0	9.625	1.80	9.24	4.81	4.43	19.18		4.202
19	12.0	9.625	1.80	8.33	4.33	4.00	31.32		8.747
20	12.0	9.625	1.80	7.88	4.01	3.87	39.15		11.77
								controling:	**3.356**

$$F_d = 0.8 + \frac{1.6}{d} \le 1.3$$

$$F_n = 1 + \frac{N_u}{24 * thk}$$

$$\rho = \frac{A_s}{\phi bd} \le 0.02$$

$$\phi V_n = \phi 0.0316 b d F_{vp} \sqrt{f'c}\left(1.1 + 63\rho\right)\left(\frac{F_d F_n}{F_c}\right)$$

$$F_c = 1 \pm \left(\frac{d}{2 * rad}\right)$$

Shear Resistance Without Stirrups **AASHTO 12.10.4.2.5**

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3 Axle Case 2

Technical Data & Load Factors

Culvert Span (S) =	28.00 ft.		
Crown Radius (Rad) =	33.82 ft.		
Bar Cover			
Outside Face (Cov_{out}) =	2.00 in		
Inside Face (Cov_{in}) =	1.50 in		
Design Section Length (b) =	12 in		
Compressive Strength (f_c) =	6.5 ksi		
Yield Strength (f_y) =	60 ksi		
Stirrup Yield Strength (f_{ystir}) =	60 ksi		
Circumferential Reinforcement Spa. (spa.) =	4.00 in		
Circumferential Reinforcement Provided (n) =	1	(n=1 for 1 layer, n=2 for multiple layers)	AASHTO
Reinforcement Type (Type) =	3	AASHTO Table	12.10.4.2.4d
1 - smooth wire or plain bar		12.10.4.4d-1	
2 - WWF (8" max spa. Smooth)			
3 - WWF (deformed) or bar (deformed)			

Resistance Factors:

ϕf - Flexure =	1.00	AASHTO Table 12.5.5-1
ϕr - Radial Tension =	0.90	AASHTO Table 12.5.5-1
ϕv - Diag Tension =	0.90	AASHTO Table 12.5.5-1
Radial Tension Process (F_{rp}) =	1.00	AASHTO 12.10.4.2.3
Diag Tension Process (F_{vp}) =	1.00	AASHTO 12.10.4.2.3

Load Factors:

	IR	OR	
LL Factor		1.35	
γ_pDC (component)	1.31		(1.25*1.05 = 1.3125)
γ_pEH (hor. At rest earth pressure)	0.86		(0.9/1.05 = 0.857)
γ_pEV	1.37		(1.3*1.05 = 1.365)

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.		OF	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Design Force Summary LRFR LOAD RATING -3 Axle Case 2

	Factored DC+EV+EH			Max Factored Total Load			Max Factored LL			
Node Number	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Thk at node (in)
1	-7.35	148.20	0.00	-17.53	286.72	0.02	-10.18	138.52	0.02	10.000
2	-7.40	145.37	0.42	-17.58	286.16	0.06	-10.18	140.80	-0.36	10.000
3	-7.47	136.94	0.84	-17.61	285.06	0.09	-10.13	148.12	-0.75	10.000
4	-7.59	122.94	1.26	-17.49	283.76	0.34	-9.89	160.82	-0.92	10.000
5	-7.78	103.28	1.68	-17.20	276.02	1.34	-9.43	172.74	-0.34	10.000
6	-8.03	77.90	2.12	-17.15	247.86	3.15	-9.12	169.96	1.03	10.000
7	-8.35	46.57	2.57	-17.72	191.70	5.50	-9.38	145.13	2.93	10.063
8	-8.71	8.90	3.07	-19.10	100.42	8.49	-10.38	91.52	5.43	10.063
9	-9.13	-35.60	3.61	-20.57	-35.87	10.95	-11.43	-0.27	7.34	10.063
10	-9.60	-87.80	4.24	-21.97	-193.04	13.00	-12.37	-105.24	8.76	10.625
11	-10.09	-149.20	4.99	-23.33	-384.11	14.54	-13.24	-234.91	9.55	12.313
12	-10.63	-221.57	5.88	-24.37	-582.74	15.16	-13.75	-361.18	9.28	15.125
13	-11.22	-306.83	6.94	-25.51	-790.43	15.89	-14.29	-483.60	8.95	19.125
14	-13.21	-407.64	1.78	-28.56	-1008.54	2.91	-15.35	-600.90	1.13	27.000
15	-15.00	-357.89	-4.27	-30.82	-877.28	-11.22	-15.82	-519.40	-6.95	18.313
16	-15.14	-300.25	-4.92	-30.33	-726.60	-12.59	-15.19	-426.35	-7.66	13.563
17	-15.27	-234.07	-5.19	-29.92	-560.77	-12.74	-14.65	-326.70	-7.55	12.000
18	-15.50	-147.08	-4.81	-29.66	-352.00	-11.46	-14.16	-204.91	-6.65	12.000
19	-15.78	-70.81	-4.33	-29.57	-171.53	-10.37	-13.79	-100.72	-6.03	12.000
20	-16.07	0.00	-4.01	-29.64	0.00	-9.84	-13.56	0.00	-5.83	12.000

Note: "-" thrust indicate compression

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3 Axle Case 2

Node	Total Fac.	Factored DC+EH+EV			Factored LL			
Number	Nu (k/ft)	Nu_D (k/ft)	Mu_D (in-k/ft)	Vu_D (k/ft)	Nu_{LL} (k/ft)	$+Mu_{LL}$ (in-k/ft)	Vu_{LL} (k/ft)	Thick (in)
1	-17.53	-7.35	148.20	0.00	-10.18	138.52	0.02	10
2	-17.58	-7.40	145.37	0.42	-10.18	140.80	0.36	10
3	-17.61	-7.47	136.94	0.84	-10.13	148.12	0.75	10
4	-17.49	-7.59	122.94	1.26	-9.89	160.82	0.92	10
5	-17.20	-7.78	103.28	1.68	-9.43	172.74	0.34	10
6	-17.15	-8.03	77.90	2.12	-9.12	169.96	1.03	10
7	-17.72	-8.35	46.57	2.57	-9.38	145.13	2.93	10.063
8	-19.10	-8.71	8.90	3.07	-10.38	91.52	5.43	10.063
9	-20.57	-9.13	-35.60	3.61	-11.43	-0.27	7.34	10.063
10	-21.97	-9.60	-87.80	4.24	-12.37	-105.24	8.76	10.625
11	-23.33	-10.09	-149.20	4.99	-13.24	-234.91	9.55	12.313
12	-24.37	-10.63	-221.57	5.88	-13.75	-361.18	9.28	15.125
13	-25.51	-11.22	-306.83	6.94	-14.29	-483.60	8.95	19.125
14	-28.56	-13.21	-407.64	1.78	-15.35	-600.90	1.13	27
15	-30.82	-15.00	-357.89	4.27	-15.82	-519.40	6.95	18.313
16	-30.33	-15.14	-300.25	4.92	-15.19	-426.35	7.66	13.563
17	-29.92	-15.27	-234.07	5.19	-14.65	-326.70	7.55	12
18	-29.66	-15.50	-147.08	4.81	-14.16	-204.91	6.65	12
19	-29.57	-15.78	-70.81	4.33	-13.79	-100.72	6.03	12
20	-29.64	-16.07	0.00	4.01	-13.56	0.00	5.83	12

note all shear values normalized to positive

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Node Number	thk (in)	d (in)	As'in (prov'd) (in^2 / ft)	As'out (prov'd) (in^2 / ft)
1	10.0	8.13	2.38	0.90
2	10.0	8.13	2.38	0.90
3	10.0	8.13	2.38	0.90
4	10.0	8.13	2.38	0.90
5	10.0	8.13	2.38	0.90
6	10.0	8.13	2.38	0.90
7	10.1	8.19	2.38	0.90
8	10.1	8.19	2.38	0.90
9	10.1	7.69	1.32	1.80
10	10.6	8.25	1.32	1.80
11	12.3	9.94	1.32	1.80
12	15.1	12.75	1.32	1.80
13	19.1	16.75	1.32	1.80
14	27.0	24.63	1.32	1.80
15	18.3	15.94	1.32	1.80
16	13.6	11.19	1.32	1.80
17	12.0	9.63	1.32	1.80
18	12.0	9.63	0.60	1.80
19	12.0	9.63	0.60	1.80
20	12.0	9.63	0.60	1.80

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3 Axle Case 2

Node Number	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Total Fac. Nu (k/ft)	Phi Mn (in-k/ft)
1	10.0	8.13	2.38	-17.53	1052.68
2	10.0	8.13	2.38	-17.58	1052.81
3	10.0	8.13	2.38	-17.61	1052.87
4	10.0	8.13	2.38	-17.49	1052.56
5	10.0	8.13	2.38	-17.20	1051.83
6	10.0	8.13	2.38	-17.15	1051.69
7	10.1	8.19	2.38	-17.72	1062.71
8	10.1	8.19	2.38	-19.10	1066.29
9	10.1	7.69	1.80	-20.57	809.13
10	10.6	8.25	1.80	-21.97	880.33
11	12.3	9.94	1.80	-23.33	1086.86
12	15.1	12.75	1.80	-24.37	1429.18
13	19.1	16.75	1.80	-25.51	1918.49
14	27.0	24.63	1.80	-28.56	2904.45
15	18.3	15.94	1.80	-30.82	1858.19
16	13.6	11.19	1.80	-30.33	1269.70
17	12.0	9.63	1.80	-29.92	1075.56
18	12.0	9.63	1.80	-29.66	1074.55
19	12.0	9.63	1.80	-29.57	1074.19
20	12.0	9.63	1.80	-29.64	1074.45

AASHTO 12.10.4.2.4a

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3 Axle Case 2

Node Number	thk (in)	d (in)	Phi Mn (in-k/ft)	Mu_D (in-k/ft)	$+Mu_{LL}$ (in-k/ft)		Operating Rating
1	10.0	8.13	1052.68	148.20	138.52		8.46
2	10.0	8.13	1052.81	145.37	140.80		8.35
3	10.0	8.13	1052.87	136.94	148.12		8.02
4	10.0	8.13	1052.56	122.94	160.82		7.49
5	10.0	8.13	1051.83	103.28	172.74		7.12
6	10.0	8.13	1051.69	77.90	169.96		7.43
7	10.1	8.19	1062.71	46.57	145.13		9.08
8	10.1	8.19	1066.29	8.90	91.52		14.98
9	10.1	7.69	809.13	-35.60	-0.27		3664.96
10	10.6	8.25	880.33	-87.80	-105.24		9.76
11	12.3	9.94	1086.86	-149.20	-234.91		5.17
12	15.1	12.75	1429.18	-221.57	-361.18		4.33
13	19.1	16.75	1918.49	-306.83	-483.60		4.32
14	27.0	24.63	2904.45	-407.64	-600.90		5.39
15	18.3	15.94	1858.19	-357.89	-519.40		3.74
16	13.6	11.19	1269.70	-300.25	-426.35		2.95
17	12.0	9.63	1075.56	-234.07	-326.70		3.34
18	12.0	9.63	1074.55	-147.08	-204.91		5.87
19	12.0	9.63	1074.19	-70.81	-100.72		12.91
20	12.0	9.63	1074.45	0.00	0.00		N/A
					Controlling		**2.95**

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA ENGINEERS
184 Court Street
BINGHAMTON, NEW YORK 13901
(607) 231-6600 Fax 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -3 Axle Case 2

Elmt Nmbr	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Vtotal (kip/ft)	Vdl only (kip/ft)	Vll only (kip/ft)	ϕVn (kip/ft)		1.35 OPR
1	10.0	8.125	2.38	0.02	0.00	0.02	19.42		1436
2	10.0	8.125	2.38	0.06	0.42	0.36	19.42		68.74
3	10.0	8.125	2.38	0.09	0.84	0.75	19.42		32.23
4	10.0	8.125	2.38	0.34	1.26	0.92	19.41		25.61
5	10.0	8.125	2.38	1.34	1.68	0.34	19.39		67.41
6	10.0	8.125	2.38	3.15	2.12	1.03	19.39		21.73
7	10.1	8.188	2.38	5.50	2.57	2.93	19.45		7.474
8	10.1	8.188	2.38	8.49	3.07	5.43	31.57		6.81
9	10.1	7.688	1.80	10.95	3.61	7.34	29.86		4.634
10	10.6	8.250	1.80	13.00	4.24	8.76	27.75		3.481
11	12.3	9.938	1.80	14.54	4.99	9.55	21.72		2.271
12	15.1	12.750	1.80	15.16	5.88	9.28	21.56		2.19
13	19.1	16.750	1.80	15.89	6.94	8.95	24.88		2.599
14	27.0	24.625	1.80	2.91	1.78	1.13	30.84		33.25
15	18.3	15.938	1.80	11.22	4.27	6.95	23.65		3.617
16	13.6	11.188	1.80	12.59	4.92	7.66	20.11		2.569
17	12.0	9.625	1.80	12.74	5.19	7.55	19.08		2.384
18	12.0	9.625	1.80	11.46	4.81	6.65	19.64		2.89
19	12.0	9.625	1.80	10.37	4.33	6.03	32.20		5.988
20	12.0	9.625	1.80	9.84	4.01	5.83	39.15		7.814
								controling:	**2.19**

$$F_d = 0.8 + \frac{1.6}{d} \le 1.3$$

$$F_n = 1 + \frac{N_u}{24 * thk}$$

$$\rho = \frac{A_s}{\phi bd} \le 0.02$$

$$\phi V_n = \phi 0.0316 b d F_{vp} \sqrt{f'c}\left(1.1 + 63\rho\right)\left(\frac{F_d F_n}{F_c}\right)$$

$$F_c = 1 \pm \left(\frac{d}{2 * rad}\right)$$

Shear Resistance Without Stirrups **AASHTO 12.10.4.2.5**

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -4 Axle Case 1

Technical Data & Load Factors

Culvert Span (S) =	28.00 ft.		
Crown Radius (Rad) =	33.82 ft.		
Bar Cover			
Outside Face (Cov_{out}) =	2.00 in		
Inside Face (Cov_{in}) =	1.50 in		
Design Section Length (b) =	12 in		
Compressive Strength (f_c) =	6.5 ksi		
Yield Strength (f_y) =	60 ksi		
Stirrup Yield Strength (f_{ystir}) =	60 ksi		
Circumferential Reinforcement Spa. (spa.) =	4.00 in		
Circumferential Reinforcement Provided (n) =	1	(n=1 for 1 layer, n=2 for multiple layers)	AASHTO
Reinforcement Type (Type) =	3	AASHTO Table	12.10.4.2.4d
1 - smooth wire or plain bar		12.10.4.4d-1	
2 - WWF (8" max spa. Smooth)			
3 - WWF (deformed) or bar (deformed)			

Resistance Factors:

ϕf - Flexure =	1.00	AASHTO Table 12.5.5-1
ϕr - Radial Tension =	0.90	
ϕv - Diag Tension =	0.90	
Radial Tension Process (F_{rp}) =	1.00	AASHTO 12.10.4.2.3
Diag Tension Process (F_{vp}) =	1.00	

Load Factors:

	IR	OR	
LL Factor		1.35	
γ_pDC (component)	1.31		(1.25*1.05 = 1.3125)
γ_pEH (hor. At rest earth pressure)	0.86		(0.9/1.05 = 0.857)
γ_pEV	1.37		(1.3*1.05 = 1.365)

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.		OF	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Design Force Summary LRFR LOAD RATING -4 Axle Case 1

	Factored DC+EV+EH			Max Factored Total Load			Max Factored LL			
Node Number	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Thk at node (in)
1	-7.35	148.20	0.00	-16.48	512.82	-0.02	-9.13	364.62	-0.03	10.000
2	-7.40	145.37	0.42	-16.65	497.11	2.36	-9.25	351.74	1.95	10.000
3	-7.47	136.94	0.84	-17.11	449.42	4.20	-9.64	312.48	3.36	10.000
4	-7.59	122.94	1.26	-17.85	384.60	5.31	-10.25	261.66	4.05	10.000
5	-7.78	103.28	1.68	-18.50	307.19	6.53	-10.72	203.90	4.85	10.000
6	-8.03	77.90	2.12	-19.26	209.56	8.06	-11.23	131.65	5.95	10.000
7	-8.35	46.57	2.57	-20.29	91.11	9.53	-11.95	44.53	6.95	10.063
8	-8.71	8.90	3.07	-21.38	-45.77	10.81	-12.67	-54.67	7.74	10.063
9	-9.13	-35.60	3.61	-22.24	-198.56	11.39	-13.11	-162.97	7.78	10.063
10	-9.60	-87.80	4.24	-22.96	-351.05	11.55	-13.37	-263.25	7.31	10.625
11	-10.09	-149.20	4.99	-23.80	-508.07	11.95	-13.71	-358.87	6.95	12.313
12	-10.63	-221.57	5.88	-24.74	-671.17	12.49	-14.11	-449.60	6.60	15.125
13	-11.22	-306.83	6.94	-25.73	-842.70	13.26	-14.51	-535.87	6.32	19.125
14	-13.21	-407.64	1.78	-27.40	-1026.58	1.13	-14.18	-618.94	-0.65	27.000
15	-15.00	-357.89	-4.27	-28.32	-882.66	-12.00	-13.32	-524.77	-7.73	18.313
16	-15.14	-300.25	-4.92	-27.76	-724.99	-12.94	-12.62	-424.74	-8.01	13.563
17	-15.27	-234.07	-5.19	-27.27	-557.33	-12.79	-12.00	-323.26	-7.60	12.000
18	-15.50	-147.08	-4.81	-26.93	-349.44	-11.40	-11.43	-202.36	-6.59	12.000
19	-15.78	-70.81	-4.33	-26.79	-170.12	-10.29	-11.01	-99.32	-5.96	12.000
20	-16.07	0.00	-4.01	-26.85	0.00	-9.75	-10.77	0.00	-5.74	12.000

Note: "-" thrust indicate compression

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -4 Axle Case 1

Node	Total Fac.	Factored DC+EH+EV			Factored LL			
Number	Nu (k/ft)	Nu_D (k/ft)	Mu_D (in-k/ft)	Vu_D (k/ft)	Nu_{LL} (k/ft)	$+Mu_{LL}$ (in-k/ft)	Vu_{LL} (k/ft)	Thick (in)
1	-16.48	-7.35	148.20	0.00	-9.13	364.62	0.03	10
2	-16.65	-7.40	145.37	0.42	-9.25	351.74	1.95	10
3	-17.11	-7.47	136.94	0.84	-9.64	312.48	3.36	10
4	-17.85	-7.59	122.94	1.26	-10.25	261.66	4.05	10
5	-18.50	-7.78	103.28	1.68	-10.72	203.90	4.85	10
6	-19.26	-8.03	77.90	2.12	-11.23	131.65	5.95	10
7	-20.29	-8.35	46.57	2.57	-11.95	44.53	6.95	10.063
8	-21.38	-8.71	8.90	3.07	-12.67	-54.67	7.74	10.063
9	-22.24	-9.13	-35.60	3.61	-13.11	-162.97	7.78	10.063
10	-22.96	-9.60	-87.80	4.24	-13.37	-263.25	7.31	10.625
11	-23.80	-10.09	-149.20	4.99	-13.71	-358.87	6.95	12.313
12	-24.74	-10.63	-221.57	5.88	-14.11	-449.60	6.60	15.125
13	-25.73	-11.22	-306.83	6.94	-14.51	-535.87	6.32	19.125
14	-27.40	-13.21	-407.64	1.78	-14.18	-618.94	0.65	27
15	-28.32	-15.00	-357.89	4.27	-13.32	-524.77	7.73	18.313
16	-27.76	-15.14	-300.25	4.92	-12.62	-424.74	8.01	13.563
17	-27.27	-15.27	-234.07	5.19	-12.00	-323.26	7.60	12
18	-26.93	-15.50	-147.08	4.81	-11.43	-202.36	6.59	12
19	-26.79	-15.78	-70.81	4.33	-11.01	-99.32	5.96	12
20	-26.85	-16.07	0.00	4.01	-10.77	0.00	5.74	12

note all shear values normalized to positive

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Node Number	thk (in)	d (in)	As'in (prov'd) (in^2 / ft)	As'out (prov'd) (in^2 / ft)
1	10.0	8.13	2.38	0.90
2	10.0	8.13	2.38	0.90
3	10.0	8.13	2.38	0.90
4	10.0	8.13	2.38	0.90
5	10.0	8.13	2.38	0.90
6	10.0	8.13	2.38	0.90
7	10.1	8.19	2.38	0.90
8	10.1	7.69	2.38	0.90
9	10.1	7.69	1.32	1.80
10	10.6	8.25	1.32	1.80
11	12.3	9.94	1.32	1.80
12	15.1	12.75	1.32	1.80
13	19.1	16.75	1.32	1.80
14	27.0	24.63	1.32	1.80
15	18.3	15.94	1.32	1.80
16	13.6	11.19	1.32	1.80
17	12.0	9.63	1.32	1.80
18	12.0	9.63	0.60	1.80
19	12.0	9.63	0.60	1.80
20	12.0	9.63	0.60	1.80

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -4 Axle Case 1

Node Number	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Total Fac. Nu (k/ft)	Phi Mn (in-k/ft)
1	10.0	8.13	2.38	-16.48	1049.95
2	10.0	8.13	2.38	-16.65	1050.39
3	10.0	8.13	2.38	-17.11	1051.58
4	10.0	8.13	2.38	-17.85	1053.49
5	10.0	8.13	2.38	-18.50	1055.17
6	10.0	8.13	2.38	-19.26	1057.13
7	10.1	8.19	2.38	-20.29	1069.37
8	10.1	7.69	0.90	-21.38	479.88
9	10.1	7.69	1.80	-22.24	814.30
10	10.6	8.25	1.80	-22.96	883.65
11	12.3	9.94	1.80	-23.80	1088.84
12	15.1	12.75	1.80	-24.74	1431.19
13	19.1	16.75	1.80	-25.73	1920.14
14	27.0	24.63	1.80	-27.40	2891.10
15	18.3	15.94	1.80	-28.32	1840.49
16	13.6	11.19	1.80	-27.76	1257.56
17	12.0	9.63	1.80	-27.27	1065.14
18	12.0	9.63	1.80	-26.93	1063.78
19	12.0	9.63	1.80	-26.79	1063.20
20	12.0	9.63	1.80	-26.85	1063.45

AASHTO 12.10.4.2.4a

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -4 Axle Case 1

Node Number	thk (in)	d (in)	Phi Mn (in-k/ft)	Mu_D (in-k/ft)	$+Mu_{LL}$ (in-k/ft)		Operating Rating
1	10.0	8.13	1049.95	148.20	364.62		3.21
2	10.0	8.13	1050.39	145.37	351.74		3.34
3	10.0	8.13	1051.58	136.94	312.48		3.79
4	10.0	8.13	1053.49	122.94	261.66		4.61
5	10.0	8.13	1055.17	103.28	203.90		6.05
6	10.0	8.13	1057.13	77.90	131.65		9.64
7	10.1	8.19	1069.37	46.57	44.53		29.77
8	10.1	7.69	479.88	8.90	-54.67		11.59
9	10.1	7.69	814.30	-35.60	-162.97		6.19
10	10.6	8.25	883.65	-87.80	-263.25		3.92
11	12.3	9.94	1088.84	-149.20	-358.87		3.39
12	15.1	12.75	1431.19	-221.57	-449.60		3.49
13	19.1	16.75	1920.14	-306.83	-535.87		3.90
14	27.0	24.63	2891.10	-407.64	-618.94		5.20
15	18.3	15.94	1840.49	-357.89	-524.77		3.66
16	13.6	11.19	1257.56	-300.25	-424.74		2.92
17	12.0	9.63	1065.14	-234.07	-323.26		3.33
18	12.0	9.63	1063.78	-147.08	-202.36		5.87
19	12.0	9.63	1063.20	-70.81	-99.32		12.95
20	12.0	9.63	1063.45	0.00	0.00		N/A
					Controlling		**2.92**

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA ENGINEERS
184 Court Street
BINGHAMTON, NEW YORK 13901
(607) 231-6600 Fax 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -4 Axle Case 1

Elmt Nmbr	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Vtotal (kip/ft)	Vdl only (kip/ft)	Vll only (kip/ft)	ϕVn (kip/ft)		1.35 OPR
1	10.0	8.125	2.38	0.02	0.00	0.03	19.34		953.7
2	10.0	8.125	2.38	2.36	0.42	1.95	19.35		12.62
3	10.0	8.125	2.38	4.20	0.84	3.36	19.38		7.152
4	10.0	8.125	2.38	5.31	1.26	4.05	19.44		5.818
5	10.0	8.125	2.38	6.53	1.68	4.85	19.49		4.758
6	10.0	8.125	2.38	8.06	2.12	5.95	19.80		3.853
7	10.1	8.188	2.38	9.53	2.57	6.95	31.57		5.406
8	10.1	7.688	0.90	10.81	3.07	7.74	29.86		4.485
9	10.1	7.688	1.80	11.39	3.61	7.78	23.54		3.32
10	10.6	8.250	1.80	11.55	4.24	7.31	17.84		2.412
11	12.3	9.938	1.80	11.95	4.99	6.95	18.91		2.594
12	15.1	12.750	1.80	12.49	5.88	6.60	20.91		2.949
13	19.1	16.750	1.80	13.26	6.94	6.32	24.04		3.508
14	27.0	24.625	1.80	1.13	1.78	0.65	30.79		57.92
15	18.3	15.938	1.80	12.00	4.27	7.73	23.53		3.23
16	13.6	11.188	1.80	12.94	4.92	8.01	19.97		2.433
17	12.0	9.625	1.80	12.79	5.19	7.60	18.92		2.342
18	12.0	9.625	1.80	11.40	4.81	6.59	19.36		2.861
19	12.0	9.625	1.80	10.29	4.33	5.96	31.52		5.914
20	12.0	9.625	1.80	9.75	4.01	5.74	39.15		7.936
								controling:	**2.342**

$$F_d = 0.8 + \frac{1.6}{d} \le 1.3$$

$$F_n = 1 + \frac{N_u}{24 * thk}$$

$$\rho = \frac{A_s}{\phi bd} \le 0.02$$

$$\phi V_n = \phi 0.0316 b d F_{vp} \sqrt{f'c}\left(1.1 + 63\rho\right)\left(\frac{F_d F_n}{F_c}\right)$$

$$F_c = 1 \pm \left(\frac{d}{2 * rad}\right)$$

Shear Resistance Without Stirrups **AASHTO 12.10.4.2.5**

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -4 Axle Case 2

Technical Data & Load Factors

Culvert Span (S) =	28.00 ft.		
Crown Radius (Rad) =	33.82 ft.		
Bar Cover			
Outside Face (Cov_{out}) =	2.00 in		
Inside Face (Cov_{in}) =	1.50 in		
Design Section Length (b) =	12 in		
Compressive Strength (f_c) =	6.5 ksi		
Yield Strength (f_y) =	60 ksi		
Stirrup Yield Strength (f_{ystir}) =	60 ksi		
Circumferential Reinforcement Spa. (spa.) =	4.00 in		
Circumferential Reinforcement Provided (n) =	1	(n=1 for 1 layer, n=2 for multiple layers)	AASHTO
Reinforcement Type (Type) =	3	AASHTO Table	12.10.4.2.4d
1 - smooth wire or plain bar		12.10.4.4d-1	
2 - WWF (8" max spa. Smooth)			
3 - WWF (deformed) or bar (deformed)			

Resistance Factors:

ϕf - Flexure =	1.00	AASHTO Table 12.5.5-1
ϕr - Radial Tension =	0.90	
ϕv - Diag Tension =	0.90	
Radial Tension Process (F_{rp}) =	1.00	AASHTO 12.10.4.2.3
Diag Tension Process (F_{vp}) =	1.00	

Load Factors:

	IR	OR	
LL Factor		1.35	
γ_pDC (component)	1.31		(1.25*1.05 = 1.3125)
γ_pEH (hor. At rest earth pressure)	0.86		(0.9/1.05 = 0.857)
γ_pEV	1.37		(1.3*1.05 = 1.365)

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.		OF	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Design Force Summary LRFR LOAD RATING -4 Axle Case 2

	Factored DC+EV+EH			Max Factored Total Load			Max Factored LL			
Node Number	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Thk at node (in)
1	-7.35	148.20	0.00	-19.14	341.69	-0.03	-11.79	193.49	-0.03	10.000
2	-7.40	145.37	0.42	-19.08	342.19	-0.05	-11.68	196.82	-0.47	10.000
3	-7.47	136.94	0.84	-18.92	343.01	0.19	-11.45	206.06	-0.65	10.000
4	-7.59	122.94	1.26	-18.66	337.12	1.20	-11.07	214.18	-0.06	10.000
5	-7.78	103.28	1.68	-18.70	310.88	2.86	-10.93	207.60	1.18	10.000
6	-8.03	77.90	2.12	-19.25	260.50	4.78	-11.22	182.59	2.66	10.000
7	-8.35	46.57	2.57	-20.32	182.84	7.00	-11.98	136.27	4.42	10.063
8	-8.71	8.90	3.07	-21.37	72.95	9.02	-12.66	64.05	5.96	10.063
9	-9.13	-35.60	3.61	-22.60	-58.91	11.25	-13.47	-23.31	7.64	10.063
10	-9.60	-87.80	4.24	-24.00	-228.48	13.28	-14.41	-140.68	9.04	10.625
11	-10.09	-149.20	4.99	-25.37	-414.77	15.01	-15.28	-265.57	10.02	12.313
12	-10.63	-221.57	5.88	-26.84	-630.76	16.56	-16.22	-409.19	10.67	15.125
13	-11.22	-306.83	6.94	-28.14	-858.44	17.49	-16.93	-551.62	10.55	19.125
14	-13.21	-407.64	1.78	-31.41	-1099.51	3.31	-18.20	-691.87	1.53	27.000
15	-15.00	-357.89	-4.27	-33.74	-956.60	-12.21	-18.75	-598.72	-7.94	18.313
16	-15.14	-300.25	-4.92	-33.15	-792.56	-13.70	-18.01	-492.31	-8.78	13.563
17	-15.27	-234.07	-5.19	-32.64	-612.13	-13.88	-17.36	-378.06	-8.69	12.000
18	-15.50	-147.08	-4.81	-32.30	-384.43	-12.51	-16.79	-237.35	-7.70	12.000
19	-15.78	-70.81	-4.33	-32.16	-187.36	-11.32	-16.38	-116.55	-6.99	12.000
20	-16.07	0.00	-4.01	-32.20	0.00	-10.75	-16.13	0.00	-6.74	12.000

Note: "-" thrust indicate compression

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -4 Axle Case 2

Node	Total Fac.	Factored DC+EH+EV			Factored LL			
Number	Nu (k/ft)	Nu_D (k/ft)	Mu_D (in-k/ft)	Vu_D (k/ft)	Nu_{LL} (k/ft)	$+Mu_{LL}$ (in-k/ft)	Vu_{LL} (k/ft)	Thick (in)
1	-19.14	-7.35	148.20	0.00	-11.79	193.49	0.03	10
2	-19.08	-7.40	145.37	0.42	-11.68	196.82	0.47	10
3	-18.92	-7.47	136.94	0.84	-11.45	206.06	0.65	10
4	-18.66	-7.59	122.94	1.26	-11.07	214.18	0.06	10
5	-18.70	-7.78	103.28	1.68	-10.93	207.60	1.18	10
6	-19.25	-8.03	77.90	2.12	-11.22	182.59	2.66	10
7	-20.32	-8.35	46.57	2.57	-11.98	136.27	4.42	10.063
8	-21.37	-8.71	8.90	3.07	-12.66	64.05	5.96	10.063
9	-22.60	-9.13	-35.60	3.61	-13.47	-23.31	7.64	10.063
10	-24.00	-9.60	-87.80	4.24	-14.41	-140.68	9.04	10.625
11	-25.37	-10.09	-149.20	4.99	-15.28	-265.57	10.02	12.313
12	-26.84	-10.63	-221.57	5.88	-16.22	-409.19	10.67	15.125
13	-28.14	-11.22	-306.83	6.94	-16.93	-551.62	10.55	19.125
14	-31.41	-13.21	-407.64	1.78	-18.20	-691.87	1.53	27
15	-33.74	-15.00	-357.89	4.27	-18.75	-598.72	7.94	18.313
16	-33.15	-15.14	-300.25	4.92	-18.01	-492.31	8.78	13.563
17	-32.64	-15.27	-234.07	5.19	-17.36	-378.06	8.69	12
18	-32.30	-15.50	-147.08	4.81	-16.79	-237.35	7.70	12
19	-32.16	-15.78	-70.81	4.33	-16.38	-116.55	6.99	12
20	-32.20	-16.07	0.00	4.01	-16.13	0.00	6.74	12

note all shear values normalized to positive

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2014.059.004
DESCRIPTION 28x10 Arch
SHEET NO ____ OF ____ SCALE ____
CALCULATED BY YL DATE 11/25/2014
CHECKED BY ____ DATE ____

Node Number	thk (in)	d (in)	As'in (prov'd) (in^2 / ft)	As'out (prov'd) (in^2 / ft)
1	10.0	8.13	2.38	0.90
2	10.0	8.13	2.38	0.90
3	10.0	8.13	2.38	0.90
4	10.0	8.13	2.38	0.90
5	10.0	8.13	2.38	0.90
6	10.0	8.13	2.38	0.90
7	10.1	8.19	2.38	0.90
8	10.1	8.19	2.38	0.90
9	10.1	7.69	1.32	1.80
10	10.6	8.25	1.32	1.80
11	12.3	9.94	1.32	1.80
12	15.1	12.75	1.32	1.80
13	19.1	16.75	1.32	1.80
14	27.0	24.63	1.32	1.80
15	18.3	15.94	1.32	1.80
16	13.6	11.19	1.32	1.80
17	12.0	9.63	1.32	1.80
18	12.0	9.63	0.60	1.80
19	12.0	9.63	0.60	1.80
20	12.0	9.63	0.60	1.80

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -4 Axle Case 2

Node Number	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Total Fac. Nu (k/ft)	Phi Mn (in-k/ft)
1	10.0	8.13	2.38	-19.14	1056.82
2	10.0	8.13	2.38	-19.08	1056.65
3	10.0	8.13	2.38	-18.92	1056.24
4	10.0	8.13	2.38	-18.66	1055.59
5	10.0	8.13	2.38	-18.70	1055.70
6	10.0	8.13	2.38	-19.25	1057.09
7	10.1	8.19	2.38	-20.32	1069.45
8	10.1	8.19	2.38	-21.37	1072.15
9	10.1	7.69	1.80	-22.60	815.40
10	10.6	8.25	1.80	-24.00	887.11
11	12.3	9.94	1.80	-25.37	1095.35
12	15.1	12.75	1.80	-26.84	1442.88
13	19.1	16.75	1.80	-28.14	1938.35
14	27.0	24.63	1.80	-31.41	2936.95
15	18.3	15.94	1.80	-33.74	1878.76
16	13.6	11.19	1.80	-33.15	1282.87
17	12.0	9.63	1.80	-32.64	1086.15
18	12.0	9.63	1.80	-32.30	1084.84
19	12.0	9.63	1.80	-32.16	1084.29
20	12.0	9.63	1.80	-32.20	1084.48

AASHTO 12.10.4.2.4a

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -4 Axle Case 2

Node Number	thk (in)	d (in)	Phi Mn (in-k/ft)	Mu_D (in-k/ft)	$+Mu_{LL}$ (in-k/ft)		Operating Rating
1	10.0	8.13	1056.82	148.20	193.49		6.09
2	10.0	8.13	1056.65	145.37	196.82		6.00
3	10.0	8.13	1056.24	136.94	206.06		5.78
4	10.0	8.13	1055.59	122.94	214.18		5.64
5	10.0	8.13	1055.70	103.28	207.60		5.95
6	10.0	8.13	1057.09	77.90	182.59		6.95
7	10.1	8.19	1069.45	46.57	136.27		9.73
8	10.1	8.19	1072.15	8.90	64.05		21.52
9	10.1	7.69	815.40	-35.60	-23.31		43.37
10	10.6	8.25	887.11	-87.80	-140.68		7.37
11	12.3	9.94	1095.35	-149.20	-265.57		4.62
12	15.1	12.75	1442.88	-221.57	-409.19		3.87
13	19.1	16.75	1938.35	-306.83	-551.62		3.83
14	27.0	24.63	2936.95	-407.64	-691.87		4.74
15	18.3	15.94	1878.76	-357.89	-598.72		3.29
16	13.6	11.19	1282.87	-300.25	-492.31		2.59
17	12.0	9.63	1086.15	-234.07	-378.06		2.92
18	12.0	9.63	1084.84	-147.08	-237.35		5.12
19	12.0	9.63	1084.29	-70.81	-116.55		11.27
20	12.0	9.63	1084.48	0.00	0.00		N/A
					Controlling		**2.59**

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA ENGINEERS
184 Court Street
BINGHAMTON, NEW YORK 13901
(607) 231-6600 Fax 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -4 Axle Case 2

Elmt Nmbr	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Vtotal (kip/ft)	Vdl only (kip/ft)	Vll only (kip/ft)	ϕVn (kip/ft)		1.35 OPR
1	10.0	8.125	2.38	0.03	0.00	0.03	19.54		901.8
2	10.0	8.125	2.38	0.05	0.42	0.47	19.53		52.8
3	10.0	8.125	2.38	0.19	0.84	0.65	19.52		37.4
4	10.0	8.125	2.38	1.20	1.26	0.06	19.50		413.2
5	10.0	8.125	2.38	2.86	1.68	1.18	19.50		19.6
6	10.0	8.125	2.38	4.78	2.12	2.66	19.55		8.489
7	10.1	8.188	2.38	7.00	2.57	4.42	20.25		5.181
8	10.1	8.188	2.38	9.02	3.07	5.96	31.57		6.205
9	10.1	7.688	1.80	11.25	3.61	7.64	29.86		4.454
10	10.6	8.250	1.80	13.28	4.24	9.04	25.30		3.019
11	12.3	9.938	1.80	15.01	4.99	10.02	21.18		2.094
12	15.1	12.750	1.80	16.56	5.88	10.67	21.86		1.94
13	19.1	16.750	1.80	17.49	6.94	10.55	25.28		2.253
14	27.0	24.625	1.80	3.31	1.78	1.53	30.97		24.8
15	18.3	15.938	1.80	12.21	4.27	7.94	23.80		3.187
16	13.6	11.188	1.80	13.70	4.92	8.78	20.27		2.267
17	12.0	9.625	1.80	13.88	5.19	8.69	19.24		2.096
18	12.0	9.625	1.80	12.51	4.81	7.70	19.79		2.522
19	12.0	9.625	1.80	11.32	4.33	6.99	32.44		5.214
20	12.0	9.625	1.80	10.75	4.01	6.74	39.15		6.76
								controling:	**1.94**

$$F_d = 0.8 + \frac{1.6}{d} \le 1.3$$

$$F_n = 1 + \frac{N_u}{24 * thk}$$

$$\rho = \frac{A_s}{\phi bd} \le 0.02$$

$$\phi V_n = \phi 0.0316 b d F_{vp} \sqrt{f'c}\left(1.1 + 63\rho\right)\left(\frac{F_d F_n}{F_c}\right)$$

$$F_c = 1 \pm \left(\frac{d}{2 * rad}\right)$$

Shear Resistance Without Stirrups **AASHTO 12.10.4.2.5**

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -5 Axle Case 1

Technical Data & Load Factors

Culvert Span (S) =	28.00 ft.		
Crown Radius (Rad) =	33.82 ft.		
Bar Cover			
Outside Face (Cov_{out}) =	2.00 in		
Inside Face (Cov_{in}) =	1.50 in		
Design Section Length (b) =	12 in		
Compressive Strength (f_c) =	6.5 ksi		
Yield Strength (f_y) =	60 ksi		
Stirrup Yield Strength (f_{ystir}) =	60 ksi		
Circumferential Reinforcement Spa. (spa.) =	4.00 in		
Circumferential Reinforcement Provided (n) =	1	(n=1 for 1 layer, n=2 for multiple layers)	AASHTO
Reinforcement Type (Type) =	3	AASHTO Table	12.10.4.2.4d
1 - smooth wire or plain bar		12.10.4.4d-1	
2 - WWF (8" max spa. Smooth)			
3 - WWF (deformed) or bar (deformed)			

Resistance Factors:

ϕf - Flexure =	1.00	AASHTO Table 12.5.5-1
ϕr - Radial Tension =	0.90	
ϕv - Diag Tension =	0.90	
Radial Tension Process (F_{rp}) =	1.00	AASHTO 12.10.4.2.3
Diag Tension Process (F_{vp}) =	1.00	

Load Factors:

	IR	OR	
LL Factor		1.35	
$\gamma_p DC$ (component)	1.31		(1.25*1.05 = 1.3125)
$\gamma_p EH$ (hor. At rest earth pressure)	0.86		(0.9/1.05 = 0.857)
$\gamma_p EV$	1.37		(1.3*1.05 = 1.365)

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.		OF	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Design Force Summary LRFR LOAD RATING -5 Axle Case 1

	Factored DC+EV+EH			Max Factored Total Load			Max Factored LL			
Node Number	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Thk at node (in)
1	-7.35	148.20	0.00	-12.55	398.65	-0.11	-5.19	250.45	-0.11	10.000
2	-7.40	145.37	0.42	-12.74	384.72	2.19	-5.34	239.35	1.77	10.000
3	-7.47	136.94	0.84	-13.28	340.04	4.13	-5.81	203.10	3.29	10.000
4	-7.59	122.94	1.26	-14.06	274.15	5.36	-6.46	151.21	4.11	10.000
5	-7.78	103.28	1.68	-14.62	196.27	5.95	-6.84	92.99	4.27	10.000
6	-8.03	77.90	2.12	-15.01	114.60	6.06	-6.98	36.69	3.94	10.000
7	-8.35	46.57	2.57	-15.39	33.99	6.12	-7.05	-12.59	3.54	10.063
8	-8.71	8.90	3.07	-15.86	-49.34	6.33	-7.15	-58.24	3.27	10.063
9	-9.13	-35.60	3.61	-16.41	-135.70	6.71	-7.28	-100.10	3.10	10.063
10	-9.60	-87.80	4.24	-17.13	-229.02	7.42	-7.53	-141.22	3.18	10.625
11	-10.09	-149.20	4.99	-17.82	-334.46	8.37	-7.73	-185.27	3.38	12.313
12	-10.63	-221.57	5.88	-18.63	-453.26	9.62	-8.01	-231.70	3.74	15.125
13	-11.22	-306.83	6.94	-19.60	-592.33	11.03	-8.38	-285.50	4.08	19.125
14	-13.21	-407.64	1.78	-21.78	-748.80	1.85	-8.57	-341.16	0.06	27.000
15	-15.00	-357.89	-4.27	-23.42	-648.49	-8.48	-8.43	-290.60	-4.21	18.313
16	-15.14	-300.25	-4.92	-23.20	-535.68	-9.39	-8.06	-235.43	-4.46	13.563
17	-15.27	-234.07	-5.19	-22.99	-412.43	-9.44	-7.72	-178.36	-4.24	12.000
18	-15.50	-147.08	-4.81	-22.89	-258.48	-8.44	-7.39	-111.40	-3.64	12.000
19	-15.78	-70.81	-4.33	-22.89	-125.65	-7.61	-7.11	-54.85	-3.28	12.000
20	-16.07	0.00	-4.01	-23.00	0.00	-7.19	-6.93	0.00	-3.18	12.000

Note: "-" thrust indicate compression

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -5 Axle Case 1

Node	Total Fac.	Factored DC+EH+EV			Factored LL			
Number	Nu (k/ft)	Nu_D (k/ft)	Mu_D (in-k/ft)	Vu_D (k/ft)	Nu_{LL} (k/ft)	$+Mu_{LL}$ (in-k/ft)	Vu_{LL} (k/ft)	Thick (in)
1	-12.55	-7.35	148.20	0.00	-5.19	250.45	0.11	10
2	-12.74	-7.40	145.37	0.42	-5.34	239.35	1.77	10
3	-13.28	-7.47	136.94	0.84	-5.81	203.10	3.29	10
4	-14.06	-7.59	122.94	1.26	-6.46	151.21	4.11	10
5	-14.62	-7.78	103.28	1.68	-6.84	92.99	4.27	10
6	-15.01	-8.03	77.90	2.12	-6.98	36.69	3.94	10
7	-15.39	-8.35	46.57	2.57	-7.05	-12.59	3.54	10.063
8	-15.86	-8.71	8.90	3.07	-7.15	-58.24	3.27	10.063
9	-16.41	-9.13	-35.60	3.61	-7.28	-100.10	3.10	10.063
10	-17.13	-9.60	-87.80	4.24	-7.53	-141.22	3.18	10.625
11	-17.82	-10.09	-149.20	4.99	-7.73	-185.27	3.38	12.313
12	-18.63	-10.63	-221.57	5.88	-8.01	-231.70	3.74	15.125
13	-19.60	-11.22	-306.83	6.94	-8.38	-285.50	4.08	19.125
14	-21.78	-13.21	-407.64	1.78	-8.57	-341.16	0.06	27
15	-23.42	-15.00	-357.89	4.27	-8.43	-290.60	4.21	18.313
16	-23.20	-15.14	-300.25	4.92	-8.06	-235.43	4.46	13.563
17	-22.99	-15.27	-234.07	5.19	-7.72	-178.36	4.24	12
18	-22.89	-15.50	-147.08	4.81	-7.39	-111.40	3.64	12
19	-22.89	-15.78	-70.81	4.33	-7.11	-54.85	3.28	12
20	-23.00	-16.07	0.00	4.01	-6.93	0.00	3.18	12

note all shear values normalized to positive

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Node Number	thk (in)	d (in)	As'in (prov'd) (in^2 / ft)	As'out (prov'd) (in^2 / ft)
1	10.0	8.13	2.38	0.90
2	10.0	8.13	2.38	0.90
3	10.0	8.13	2.38	0.90
4	10.0	8.13	2.38	0.90
5	10.0	8.13	2.38	0.90
6	10.0	8.13	2.38	0.90
7	10.1	8.19	2.38	0.90
8	10.1	7.69	2.38	0.90
9	10.1	7.69	1.32	1.80
10	10.6	8.25	1.32	1.80
11	12.3	9.94	1.32	1.80
12	15.1	12.75	1.32	1.80
13	19.1	16.75	1.32	1.80
14	27.0	24.63	1.32	1.80
15	18.3	15.94	1.32	1.80
16	13.6	11.19	1.32	1.80
17	12.0	9.63	1.32	1.80
18	12.0	9.63	0.60	1.80
19	12.0	9.63	0.60	1.80
20	12.0	9.63	0.60	1.80

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -5 Axle Case 1

Node Number	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Total Fac. Nu (k/ft)	Phi Mn (in-k/ft)
1	10.0	8.13	2.38	-12.55	1039.60
2	10.0	8.13	2.38	-12.74	1040.12
3	10.0	8.13	2.38	-13.28	1041.55
4	10.0	8.13	2.38	-14.06	1043.60
5	10.0	8.13	2.38	-14.62	1045.08
6	10.0	8.13	2.38	-15.01	1046.10
7	10.1	8.19	2.38	-15.39	1056.58
8	10.1	7.69	0.90	-15.86	458.15
9	10.1	7.69	1.80	-16.41	796.15
10	10.6	8.25	1.80	-17.13	863.92
11	12.3	9.94	1.80	-17.82	1063.65
12	15.1	12.75	1.80	-18.63	1396.97
13	19.1	16.75	1.80	-19.60	1873.66
14	27.0	24.63	1.80	-21.78	2826.48
15	18.3	15.94	1.80	-23.42	1805.53
16	13.6	11.19	1.80	-23.20	1235.81
17	12.0	9.63	1.80	-22.99	1048.06
18	12.0	9.63	1.80	-22.89	1047.63
19	12.0	9.63	1.80	-22.89	1047.66
20	12.0	9.63	1.80	-23.00	1048.10

AASHTO 12.10.4.2.4a

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -5 Axle Case 1

Node Number	thk (in)	d (in)	Phi Mn (in-k/ft)	Mu_D (in-k/ft)	$+Mu_{LL}$ (in-k/ft)		Operating Rating
1	10.0	8.13	1039.60	148.20	250.45		4.61
2	10.0	8.13	1040.12	145.37	239.35		4.85
3	10.0	8.13	1041.55	136.94	203.10		5.77
4	10.0	8.13	1043.60	122.94	151.21		7.89
5	10.0	8.13	1045.08	103.28	92.99		13.13
6	10.0	8.13	1046.10	77.90	36.69		34.20
7	10.1	8.19	1056.58	46.57	-12.59		113.62
8	10.1	7.69	458.15	8.90	-58.24		10.40
9	10.1	7.69	796.15	-35.60	-100.10		9.85
10	10.6	8.25	863.92	-87.80	-141.22		7.12
11	12.3	9.94	1063.65	-149.20	-185.27		6.40
12	15.1	12.75	1396.97	-221.57	-231.70		6.58
13	19.1	16.75	1873.66	-306.83	-285.50		7.11
14	27.0	24.63	2826.48	-407.64	-341.16		9.19
15	18.3	15.94	1805.53	-357.89	-290.60		6.46
16	13.6	11.19	1235.81	-300.25	-235.43		5.15
17	12.0	9.63	1048.06	-234.07	-178.36		5.92
18	12.0	9.63	1047.63	-147.08	-111.40		10.48
19	12.0	9.63	1047.66	-70.81	-54.85		23.09
20	12.0	9.63	1048.10	0.00	0.00		N/A
					Controlling		**4.61**

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA ENGINEERS
184 Court Street
BINGHAMTON, NEW YORK 13901
(607) 231-6600 Fax 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -5 Axle Case 1

Elmt Nmbr	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Vtotal (kip/ft)	Vdl only (kip/ft)	Vll only (kip/ft)	ϕVn (kip/ft)		1.35 OPR
1	10.0	8.125	2.38	0.11	0.00	0.11	19.04		220.4
2	10.0	8.125	2.38	2.19	0.42	1.77	19.06		13.68
3	10.0	8.125	2.38	4.13	0.84	3.29	19.10		7.196
4	10.0	8.125	2.38	5.36	1.26	4.11	19.15		5.647
5	10.0	8.125	2.38	5.95	1.68	4.27	19.20		5.313
6	10.0	8.125	2.38	6.06	2.12	3.94	25.17		7.585
7	10.1	8.188	2.38	6.12	2.57	3.54	31.57		10.61
8	10.1	7.688	0.90	6.33	3.07	3.27	29.86		10.63
9	10.1	7.688	1.80	6.71	3.61	3.10	20.98		7.272
10	10.6	8.250	1.80	7.42	4.24	3.18	17.47		5.396
11	12.3	9.938	1.80	8.37	4.99	3.38	18.56		5.207
12	15.1	12.750	1.80	9.62	5.88	3.74	20.58		5.094
13	19.1	16.750	1.80	11.03	6.94	4.08	23.74		5.33
14	27.0	24.625	1.80	1.85	1.78	0.06	30.53		581.5
15	18.3	15.938	1.80	8.48	4.27	4.21	23.28		5.856
16	13.6	11.188	1.80	9.39	4.92	4.46	19.71		4.294
17	12.0	9.625	1.80	9.44	5.19	4.24	18.66		4.116
18	12.0	9.625	1.80	8.44	4.81	3.64	19.35		5.185
19	12.0	9.625	1.80	7.61	4.33	3.28	31.85		10.87
20	12.0	9.625	1.80	7.19	4.01	3.18	39.15		14.32
								controling:	**4.116**

$$F_d = 0.8 + \frac{1.6}{d} \le 1.3$$

$$F_n = 1 + \frac{N_u}{24 * thk}$$

$$\rho = \frac{A_s}{\phi bd} \le 0.02$$

$$\phi V_n = \phi 0.0316 b d F_{vp} \sqrt{f'c}\left(1.1 + 63\rho\right)\left(\frac{F_d F_n}{F_c}\right)$$

$$F_c = 1 \pm \left(\frac{d}{2 * rad}\right)$$

Shear Resistance Without Stirrups **AASHTO 12.10.4.2.5**

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -5 Axle Case 2

Technical Data & Load Factors

Culvert Span (S) =	28.00 ft.		
Crown Radius (Rad) =	33.82 ft.		
Bar Cover			
Outside Face (Cov_{out}) =	2.00 in		
Inside Face (Cov_{in}) =	1.50 in		
Design Section Length (b) =	12 in		
Compressive Strength (f_c) =	6.5 ksi		
Yield Strength (f_y) =	60 ksi		
Stirrup Yield Strength (f_{ystir}) =	60 ksi		
Circumferential Reinforcement Spa. (spa.) =	4.00 in		
Circumferential Reinforcement Provided (n) =	1	(n=1 for 1 layer, n=2 for multiple layers)	AASHTO
Reinforcement Type (Type) =	3	AASHTO Table	12.10.4.2.4d
1 - smooth wire or plain bar		12.10.4.4d-1	
2 - WWF (8" max spa. Smooth)			
3 - WWF (deformed) or bar (deformed)			

Resistance Factors:

ϕf - Flexure =	1.00	AASHTO Table 12.5.5-1
ϕr - Radial Tension =	0.90	AASHTO Table 12.5.5-1
ϕv - Diag Tension =	0.90	AASHTO Table 12.5.5-1
Radial Tension Process (F_{rp}) =	1.00	AASHTO 12.10.4.2.3
Diag Tension Process (F_{vp}) =	1.00	AASHTO 12.10.4.2.3

Load Factors:

	IR	OR	
LL Factor		1.35	
γ_pDC (component)	1.31		(1.25*1.05 = 1.3125)
γ_pEH (hor. At rest earth pressure)	0.86		(0.9/1.05 = 0.857)
γ_pEV	1.37		(1.3*1.05 = 1.365)

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.		OF	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Design Force Summary LRFR LOAD RATING -5 Axle Case 2

	Factored DC+EV+EH			Max Factored Total Load			Max Factored LL			
Node Number	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Factored Thrust Nu (k/ft)	Factored Moment Mu (k-in/ft)	Factored Shear Vu (k/ft)	Thk at node (in)
1	-7.35	148.20	0.00	-14.55	245.09	0.02	-7.20	96.89	0.01	10.000
2	-7.40	145.37	0.42	-14.61	243.98	0.15	-7.21	98.62	-0.27	10.000
3	-7.47	136.94	0.84	-14.67	241.08	0.28	-7.19	104.14	-0.56	10.000
4	-7.59	122.94	1.26	-14.65	236.59	0.56	-7.06	113.65	-0.70	10.000
5	-7.78	103.28	1.68	-14.55	226.04	1.39	-6.78	122.76	-0.29	10.000
6	-8.03	77.90	2.12	-14.61	199.21	2.86	-6.58	121.31	0.74	10.000
7	-8.35	46.57	2.57	-15.08	149.51	4.71	-6.74	102.93	2.13	10.063
8	-8.71	8.90	3.07	-16.12	73.06	6.91	-7.40	64.16	3.85	10.063
9	-9.13	-35.60	3.61	-17.29	-35.70	8.79	-8.16	-0.11	5.18	10.063
10	-9.60	-87.80	4.24	-18.45	-162.38	10.41	-8.85	-74.58	6.17	10.625
11	-10.09	-149.20	4.99	-19.56	-314.77	11.70	-9.47	-165.58	6.71	12.313
12	-10.63	-221.57	5.88	-20.51	-475.86	12.42	-9.88	-254.29	6.54	15.125
13	-11.22	-306.83	6.94	-21.56	-647.57	13.28	-10.34	-340.74	6.34	19.125
14	-13.21	-407.64	1.78	-24.25	-831.85	2.58	-11.04	-424.21	0.80	27.000
15	-15.00	-357.89	-4.27	-26.28	-723.85	-9.23	-11.28	-365.96	-4.96	18.313
16	-15.14	-300.25	-4.92	-25.98	-599.82	-10.39	-10.84	-299.57	-5.46	13.563
17	-15.27	-234.07	-5.19	-25.73	-462.67	-10.53	-10.46	-228.60	-5.34	12.000
18	-15.50	-147.08	-4.81	-25.60	-290.18	-9.46	-10.10	-143.10	-4.66	12.000
19	-15.78	-70.81	-4.33	-25.59	-141.26	-8.55	-9.81	-70.46	-4.21	12.000
20	-16.07	0.00	-4.01	-25.69	0.00	-8.09	-9.62	0.00	-4.09	12.000

Note: "-" thrust indicate compression

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -5 Axle Case 2

Node	Total Fac.	Factored DC+EH+EV			Factored LL			
Number	Nu (k/ft)	Nu_D (k/ft)	Mu_D (in-k/ft)	Vu_D (k/ft)	Nu_{LL} (k/ft)	$+Mu_{LL}$ (in-k/ft)	Vu_{LL} (k/ft)	Thick (in)
1	-14.55	-7.35	148.20	0.00	-7.20	96.89	0.01	10
2	-14.61	-7.40	145.37	0.42	-7.21	98.62	0.27	10
3	-14.67	-7.47	136.94	0.84	-7.19	104.14	0.56	10
4	-14.65	-7.59	122.94	1.26	-7.06	113.65	0.70	10
5	-14.55	-7.78	103.28	1.68	-6.78	122.76	0.29	10
6	-14.61	-8.03	77.90	2.12	-6.58	121.31	0.74	10
7	-15.08	-8.35	46.57	2.57	-6.74	102.93	2.13	10.063
8	-16.12	-8.71	8.90	3.07	-7.40	64.16	3.85	10.063
9	-17.29	-9.13	-35.60	3.61	-8.16	-0.11	5.18	10.063
10	-18.45	-9.60	-87.80	4.24	-8.85	-74.58	6.17	10.625
11	-19.56	-10.09	-149.20	4.99	-9.47	-165.58	6.71	12.313
12	-20.51	-10.63	-221.57	5.88	-9.88	-254.29	6.54	15.125
13	-21.56	-11.22	-306.83	6.94	-10.34	-340.74	6.34	19.125
14	-24.25	-13.21	-407.64	1.78	-11.04	-424.21	0.80	27
15	-26.28	-15.00	-357.89	4.27	-11.28	-365.96	4.96	18.313
16	-25.98	-15.14	-300.25	4.92	-10.84	-299.57	5.46	13.563
17	-25.73	-15.27	-234.07	5.19	-10.46	-228.60	5.34	12
18	-25.60	-15.50	-147.08	4.81	-10.10	-143.10	4.66	12
19	-25.59	-15.78	-70.81	4.33	-9.81	-70.46	4.21	12
20	-25.69	-16.07	0.00	4.01	-9.62	0.00	4.09	12

note all shear values normalized to positive

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

Node Number	thk (in)	d (in)	As'in (prov'd) (in^2 / ft)	As'out (prov'd) (in^2 / ft)
1	10.0	8.13	2.38	0.90
2	10.0	8.13	2.38	0.90
3	10.0	8.13	2.38	0.90
4	10.0	8.13	2.38	0.90
5	10.0	8.13	2.38	0.90
6	10.0	8.13	2.38	0.90
7	10.1	8.19	2.38	0.90
8	10.1	8.19	2.38	0.90
9	10.1	7.69	1.32	1.80
10	10.6	8.25	1.32	1.80
11	12.3	9.94	1.32	1.80
12	15.1	12.75	1.32	1.80
13	19.1	16.75	1.32	1.80
14	27.0	24.63	1.32	1.80
15	18.3	15.94	1.32	1.80
16	13.6	11.19	1.32	1.80
17	12.0	9.63	1.32	1.80
18	12.0	9.63	0.60	1.80
19	12.0	9.63	0.60	1.80
20	12.0	9.63	0.60	1.80

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -5 Axle Case 2

Node Number	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Total Fac. Nu (k/ft)	Phi Mn (in-k/ft)
1	10.0	8.13	2.38	-14.55	1044.90
2	10.0	8.13	2.38	-14.61	1045.05
3	10.0	8.13	2.38	-14.67	1045.20
4	10.0	8.13	2.38	-14.65	1045.17
5	10.0	8.13	2.38	-14.55	1044.91
6	10.0	8.13	2.38	-14.61	1045.06
7	10.1	8.19	2.38	-15.08	1055.76
8	10.1	8.19	2.38	-16.12	1058.50
9	10.1	7.69	1.80	-17.29	798.93
10	10.6	8.25	1.80	-18.45	868.43
11	12.3	9.94	1.80	-19.56	1071.03
12	15.1	12.75	1.80	-20.51	1407.54
13	19.1	16.75	1.80	-21.56	1888.54
14	27.0	24.63	1.80	-24.25	2855.02
15	18.3	15.94	1.80	-26.28	1825.98
16	13.6	11.19	1.80	-25.98	1249.12
17	12.0	9.63	1.80	-25.73	1059.00
18	12.0	9.63	1.80	-25.60	1058.50
19	12.0	9.63	1.80	-25.59	1058.45
20	12.0	9.63	1.80	-25.69	1058.84

AASHTO 12.10.4.2.4a

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA
ENGINEERS, ARCHITECTS, & LAND SURVEYORS
860 Hooper Road, Endwell, NY 13760
www.deltaengineers.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -5 Axle Case 2

Node Number	thk (in)	d (in)	Phi Mn (in-k/ft)	Mu_D (in-k/ft)	$+Mu_{LL}$ (in-k/ft)		Operating Rating
1	10.0	8.13	1044.90	148.20	96.89		12.00
2	10.0	8.13	1045.05	145.37	98.62		11.83
3	10.0	8.13	1045.20	136.94	104.14		11.31
4	10.0	8.13	1045.17	122.94	113.65		10.52
5	10.0	8.13	1044.91	103.28	122.76		9.94
6	10.0	8.13	1045.06	77.90	121.31		10.33
7	10.1	8.19	1055.76	46.57	102.93		12.71
8	10.1	8.19	1058.50	8.90	64.16		21.20
9	10.1	7.69	798.93	-35.60	-0.11		9265.00
10	10.6	8.25	868.43	-87.80	-74.58		13.57
11	12.3	9.94	1071.03	-149.20	-165.58		7.22
12	15.1	12.75	1407.54	-221.57	-254.29		6.05
13	19.1	16.75	1888.54	-306.83	-340.74		6.02
14	27.0	24.63	2855.02	-407.64	-424.21		7.48
15	18.3	15.94	1825.98	-357.89	-365.96		5.20
16	13.6	11.19	1249.12	-300.25	-299.57		4.11
17	12.0	9.63	1059.00	-234.07	-228.60		4.68
18	12.0	9.63	1058.50	-147.08	-143.10		8.26
19	12.0	9.63	1058.45	-70.81	-70.46		18.17
20	12.0	9.63	1058.84	0.00	0.00		N/A
					Controlling		**4.11**

g = 0.85 b f'c = 66

$$\phi M_n = \frac{1}{2}\left[g(\phi_f d)^2 - Nu(2\phi_f d - h) - \frac{(g\phi_f d - N_u - A_s F_y)^2}{g} \right]$$

DELTA ENGINEERS
184 Court Street
BINGHAMTON, NEW YORK 13901
(607) 231-6600 Fax 231-6650

JOB	2014.059.004		
DESCRIPTION	28x10 Arch		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	11/25/2014
CHECKED BY		DATE	

LRFR LOAD RATING -5 Axle Case 2

Elmt Nmbr	thk (in)	d (in)	As (prov'd) (in^2 / ft)	Vtotal (kip/ft)	Vdl only (kip/ft)	Vll only (kip/ft)	ϕVn (kip/ft)		1.35 OPR
1	10.0	8.125	2.38	0.02	0.00	0.01	19.19		1902
2	10.0	8.125	2.38	0.15	0.42	0.27	19.20		90.07
3	10.0	8.125	2.38	0.28	0.84	0.56	19.20		42.39
4	10.0	8.125	2.38	0.56	1.26	0.70	19.20		33.46
5	10.0	8.125	2.38	1.39	1.68	0.29	19.19		79.48
6	10.0	8.125	2.38	2.86	2.12	0.74	19.20		29.94
7	10.1	8.188	2.38	4.71	2.57	2.13	19.25		10.14
8	10.1	8.188	2.38	6.91	3.07	3.85	31.57		9.609
9	10.1	7.688	1.80	8.79	3.61	5.18	29.86		6.572
10	10.6	8.250	1.80	10.41	4.24	6.17	26.59		4.692
11	12.3	9.938	1.80	11.70	4.99	6.71	21.21		3.135
12	15.1	12.750	1.80	12.42	5.88	6.54	21.42		3.082
13	19.1	16.750	1.80	13.28	6.94	6.34	25.07		3.706
14	27.0	24.625	1.80	2.58	1.78	0.80	30.64		47
15	18.3	15.938	1.80	9.23	4.27	4.96	23.42		5.006
16	13.6	11.188	1.80	10.39	4.92	5.46	19.87		3.546
17	12.0	9.625	1.80	10.53	5.19	5.34	18.83		3.309
18	12.0	9.625	1.80	9.46	4.81	4.66	19.49		4.088
19	12.0	9.625	1.80	8.55	4.33	4.21	32.07		8.533
20	12.0	9.625	1.80	8.09	4.01	4.09	39.15		11.15
								controling:	**3.082**

$$F_d = 0.8 + \frac{1.6}{d} \le 1.3$$

$$F_n = 1 + \frac{N_u}{24 * thk}$$

$$\rho = \frac{A_s}{\phi bd} \le 0.02$$

$$\phi V_n = \phi 0.0316 b d F_{vp} \sqrt{f'c}\left(1.1 + 63\rho\right)\left(\frac{F_d F_n}{F_c}\right)$$

$$F_c = 1 \pm \left(\frac{d}{2 * rad}\right)$$

Shear Resistance Without Stirrups **AASHTO 12.10.4.2.5**

28x10HL93c1Mod.out

```
*** WELCOME TO CANDE-2013(version 3/1/2013) ***

MASTER CONTROL AND PIPE-TYPE DATA FOR PROBLEM #  1

        USER TITLE: 28x10

        EXECUTION MODE ..................   ANALYS

        SOLUTION LEVEL ..................  #2 AUTO

        METHODOLOGY (LRFD OR SERVICE) ...     LRFD

        NUMBER OF PIPE-ELEMENT GROUPS ....       1

        MAXIMUM ITERATIONS PER STEP ......      30


        CULVERT PIPE-TYPE ............... CONCRETE

        CANNED MESH CODE # ..............        3

        NUMBER OF BEAM ELEMENTS .........       19

        CONCRETE MATERIAL PROPERTIES ARE AS FOLLOWS

             COMPRESSION STRENGTH (psi)..........       6500.000

             ELASTIC YOUNGS MODULUS (psi)........    4595487.000

             POISSON RATIO ......................          0.170

             CONCRETE DENSITY (pcf) .............        150.000

             INITIAL TENSILE CRACKING STRAIN.....       0.000010

             INITIAL COMPRESSION YIELD STRAIN....       0.000687

             INITIAL COMPRESSION CRUSH STRAIN ...       0.002000

             SHEAR STRENGTH MODEL (NSHEAR) # ...          1
             (VARIABLE STRENGTH MODEL PRINTED IN OUTPUT)

             CONCRETE CRACK-WIDTH MODEL NAME.....   HEGER-McGRATH
             (DRIVEN BY TENSILE STRAIN IN STEEL)

        STEEL REINFORCEMENT MATERIAL PROPERTIES

             TYPE OF STEEL CAGES (RSHAPE) .......     ARBIT

             STEEL YIELD STRENGTH (psi)..........      60000.000

             STEEL ELASTIC MODULUS (psi).........   29000000.000
```

28x10HL93c1Mod.out

STEEL POISSON RATIO 0.300000

STEEL YIELDING STRAIN 0.001883

NONLINEAR MODELING CODE (1,2,3) 3

STEEL-BASED CRACKWIDTH PREDICTION PARAMETERS
REBAR SPACING INNER ROW (SLI), (in) 4.00
REBAR SPACING OUTER ROW (SLO), (in) 4.00
NUMBER OF STEEL LAYERS FOR INNER CAGE 1
NUMBER OF STEEL LAYERS FOR OUTER CAGE 1
HEGER-MCGRATH CODE NUMBER FOR STEEL TYPE.. 3

WALL THICKNESS, REBAR AREAS AND COVER DEPTHS

WALL-THICK	INNER-REBAR	OUTER-REBAR	INNER-COVER	OUTER COVER
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1100	0.1500	2.0000	2.4375
10.6250	0.1100	0.1500	2.0000	2.4375
12.3130	0.1100	0.1500	2.0000	2.4375
15.1250	0.1100	0.1500	2.0000	2.4375
19.1250	0.1100	0.1500	2.0000	2.4375
27.0000	0.1100	0.1500	2.0000	2.4375
18.3130	0.1100	0.1500	2.0000	2.4375
13.5630	0.1100	0.1500	2.0000	2.4375
12.0000	0.1100	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375

LRFD RESISTANCE FACTORS FOR STRENGTH-LIMIT STATES
AND CRACK-WIDTH LIMIT AT SERVICE LOAD

YIELDING OF REINFORCEMENT STEEL 1.000

CRUSHING OF CONCRETE OUTER FIBER..... 0.750

SHEARING FAILURE OF CONCRETE 0.900

SPLITTING OF CONCRETE IN RADIAL TENSION 0.900

ALLOWABLE CRACKWIDTH SERVICE LOAD (inch).... 0.010

LARGE DEFORMATION/BUCKLING CODE, IBUCK = 0
IBUCK=0, MEANS SMALL DEFORMATION THEORY FOR GROUP
AND NO BUCKLING PREDICTION.

28x10HL93c1Mod.out

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


 REVIEW SYSTEM INPUT DATA


 LEVEL-2 DATA FOR ARCH-TYPE CANNED MESH


    *** MESH PARAMETERS ***
     TYPE OF MESH ------------------------------------- TREN
     DEPTH OF TRENCH ABOVE FOOTING LEVEL (FT) ---------   12.42
     WIDTH OF TRENCH AT FOOTING LEVEL (FT) ------------    5.00
     SLOPE OF TRENCH WALL (H/V) -----------------------    0.00
     MESH SPACING PARAMETER ---------------------------    1.00
     TOTAL SOIL HEIGHT ABOVE CROWN (FT) ---------------    2.00
     MESH HEIGHT ABOVE CROWN (FT) ----------------------    2.00
     SOIL DENSITY ABOVE MESH (PCF) --------------------  140.00
     NUMBER OF ELEMENT LAYERS ABOVE CROWN -------------    3


*** ARCH PARAMETERS ***
     CENTERLINE RISE OF ARCH (IN) ----------------------  125.00
     BOTTOM HALF SPAN OF ARCH (IN) ---------------------  174.00
     SIDE RISE OF ARCH ABOVE FOOTING (IN) -------------   50.94
     FOOTING DEPTH (IN) --------------------------------   24.00
     OUTSIDE FOOTING WIDTH (IN) ------------------------   30.00
     INSIDE FOOTING WIDTH (IN) -------------------------   30.00
     NUMBER OF ARCH SEGMENTS DEFINED -------------------    3

*** CURVED TOP SEGMENT ***
     RADIUS (IN) ---------------------------------------  405.88
     CENTRAL ANGLE (DEG) -------------------------------   24.59
     SEGMENT ARC LENGTH (IN) ---------------------------  174.19
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------   13

*** CURVED CORNER SEGMENT ***
     RADIUS (IN) ---------------------------------------  133.94
     CENTRAL ANGLE (DEG) -------------------------------   16.14
     SEGMENT ARC LENGTH (IN) ---------------------------   37.73
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

*** STRAIGHT SIDE SEGMENT ***
     DEFLECTION ANGLE (DEG) ----------------------------   90.00
     SEGMENT LENGTH (IN) -------------------------------   50.94
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

 FINITE ELEMENT INPUT CONTROLS (PREP)


THE DATA TO BE RUN IS ENTITLED ...

New Level 2 arch mesh

PRINT AND PLOT CONTROL CODES ...
  PRINT CONTROL FOR MESH DATA------------    1
  PLOT FILE CONTROL MESH & RESULS--------    3
  PRINT FINITE ELEMENT RESULTS ----------    1
  INPUT DATA CHECK CODE------------------    0
```

28x10HL93c1Mod.out

```
 KEY NUMBERS DESCRIBING MESH ...
   THE NUMBER OF LOAD STEPS IS------------   13
   TOTAL NUMBER OF NODES IS---------------  244
   TOTAL NUMBER OF ELEMENTS IS------------  209
   TOTAL NUMBER OF BEAM ELEMENTS IS-------   19
   MAX NUMBER OF BOUNDARY CONDITIONS IS---   36



  EXTENDED LEVEL-2: CHANGES TO CANNED MESH


           * NUMBER OF NODES TO BE CHANGED -------      0 *
           * NUMBER OF ELEMENTS TO BE CHANGED ----      0 *
           * ADDITIONAL BOUNDARY CONDITIONS ------     31 *



 * * * BOUNDARY CONDITIONS * * *
  (FORCES = LBS; DISPLACEMENTS = INCHES; ROTATIONS = DEGREES)

  BOUNDARY      LOAD      X-FORCE     OR      Y-FORCE     OR      X-Y ROTATION
BEAM ROTATIONAL
     NODE       STEP      X-DISPLACEMENT      Y-DISPLACEMENT
BOUNDARY CONDITIONS

      224        10    F =   0.0000E+00    F =  -0.8925E+02      0.0000E+00
     F
      224        11    F =   0.0000E+00    F =  -0.8925E+02      0.0000E+00
     F
      224        12    F =   0.0000E+00    F =  -0.8925E+02      0.0000E+00
     F
      224        13    F =   0.0000E+00    F =  -0.8925E+02      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        11    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        12    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        13    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      224        10    F =   0.0000E+00    F =  -0.4800E+01      0.0000E+00
     F
      225        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      226        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      227        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      228        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
```

```
F
 231        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
F
 232        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
F
 233        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
F
 224         9    F =   0.0000E+00    F =  -0.2188E+01      0.0000E+00
F
 225         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 226         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 227         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 228         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 229         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 230         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 231         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 232         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 233         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 234         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 235         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 236         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F

* * * * * COMPLETED MESH GENERATION  * * * * *

New Level 2 arch mesh

CALCULATED KEY NUMBERS ...
  THE NUMBER OF DATA ERRORS IS-----------    0
  THE NUMBER OF SOIL MATERIALS IS--------    3
  THE NUMBER OF PIPE-TYPE GROUPS IS------    1
  THE NUMBER OF INTERFACE MATERIALS IS---   19
  BAND WIDTH ESTIMATE (MAX)--------------   88


* * * * MESH DATA HAS BEEN SAVED ON UNIT 14 * * * *


 BEAM-NODE SEQUENCE NUMBERS FOR EACH GROUP


    BEAM-ELEMENT GROUP NUMBER =    1

     BEAM-NODE       MESH-NODE      CONNECTED-GROUP-ELEMENTS
     SEQUENCE        NUMBER         FOREWARD-#    BACKWARD-#
         1             198              1              0
         2             194              2              1
         3             190              3              2
         4             167              4              3
```

5	164	5	4
6	161	6	5
7	158	7	6
8	138	8	7
9	136	9	8
10	134	10	9
11	132	11	10
12	130	12	11
13	128	13	12
14	118	14	13
15	115	15	14
16	109	16	15
17	103	17	16
18	97	18	17
19	91	19	18
20	80	0	19

```
MATERIAL DESCRIPTION FOR SOILS AND INTERFACE
(ALL DENSITY UNITS ARE pcf, ALL MODULUS UNITS ARE psi)

   PROPERTIES FOR MATERIAL  1   ********in site

        DENSITY =    0.14000E+03

        YOUNGS MODULUS= 0.5000E+04
        POISSONS RATIO= 0.3500E+00
        CONFINED MOD.= 0.8025E+04
        LATERAL COEFF.= 0.5385E+00

   PROPERTIES FOR MATERIAL  2   ********Footing

        DENSITY =    0.15000E+03

        YOUNGS MODULUS= 0.3122E+07
        POISSONS RATIO= 0.1700E+00
        CONFINED MOD.= 0.3356E+07
        LATERAL COEFF.= 0.2048E+00

   PROPERTIES FOR MATERIAL  3   ********SW95

        DENSITY =    0.14000E+03

   CONTROLS FOR DUNCAN SOIL MODEL
   WITH SELIG HYPERBOLIC BULK MODULUS FORMULATION

         LRFD STRESS CONTROL..........        0

         ENTERING ELEMENT RATIO.......       0.5000


   HYPERBOLIC STRESS-STRAIN PARAMETERS


         SOIL CLASSIFICATION .............SW95
```

COHESION INTERCEPT C 0.0000

FRICTION ANGLE PHIO (DEG)..... 48.0000

10-FOLD REDUCTION IN PHIO(DEG).. 8.0000

SCALED MODULUS NUMBER ZK 950.0000

MODULUS EXPONENT ZN 0.6000

FAILURE RATIO RF 0.7000

INIT. BULK MODULUS NUMBER BI.... 74.8000

ULT. VOLUMETRIC STRAIN EU 0.0200

INTERFACE ELEMENT MATERIAL-GROUP PROPERTIES

MAT. NO.	NORMAL-ANGLE	COEF-FRICTION	TENSILE-RUPTURE	INITIAL-GAP
1	90.00	0.40000	10.00000	0.00000
2	88.11	0.40000	10.00000	0.00000
3	86.22	0.40000	10.00000	0.00000
4	84.32	0.40000	10.00000	0.00000
5	82.43	0.40000	10.00000	0.00000
6	80.54	0.40000	10.00000	0.00000
7	78.65	0.40000	10.00000	0.00000
8	76.76	0.40000	10.00000	0.00000
9	74.87	0.40000	10.00000	0.00000
10	72.97	0.40000	10.00000	0.00000
11	71.08	0.40000	10.00000	0.00000
12	69.19	0.40000	10.00000	0.00000
13	67.30	0.40000	10.00000	0.00000
14	65.41	0.40000	10.00000	0.00000
15	10.46	0.40000	10.00000	0.00000
16	5.11	0.40000	10.00000	0.00000
17	0.00	0.40000	10.00000	0.00000
18	0.00	0.40000	10.00000	0.00000
19	0.00	0.40000	10.00000	0.00000

LRFD TOTAL LOAD FACTORS PER LOAD STEP

LOAD STEP	LOAD FACTOR	USER COMMENT
1	1.310	Factor for load step #1
2	0.857	Factor for load step #2
3	0.857	Factor for load step #3
4	0.857	Factor for load step #4
5	1.365	Factor for load step #5
6	1.365	Factor for load step #6
7	1.365	Factor for load step #7

28x10HL93c1Mod.out

8	1.365	Factor for load step #8
9	1.500	Factor for load step #9
10	1.750	Factor for load step #10
11	1.750	Factor for load step #11
12	1.750	Factor for load step #12
13	1.750	Factor for load step #13

+ +

SOLUTION OUTPUT RESULTS

+ +

FINITE ELEMENT OUTPUT FOR LOAD STEP 9

+ +

CONCRETE, FACTORED-EVALUATION FOR GROUP 1, LOAD-STEP 9

STRUCTURAL RESPONSES OF CONCRETE-GROUP 1, LOAD-STEP 9
COORDINATES, DISPLACEMENTS AND CRACK DEPTHS ARE INCHES
Y-BAR IS "NEUTRAL AXIS" LOCATION FROM INTERIOR, INCHES
PRESSURES ARE LB/IN**2
MOMENTS ARE IN-LB/IN
THRUST AND SHEAR ARE LB/IN

LOCAL NODE	X-COORD. Y-COORD.	X-DISP. Y-DISP.	N-PRES. S-PRES.	MOMENT THRUST	Y-BAR CRACK DEPTH
1	0.00	0.00000E+00	-0.32256E+01	0.12350E+05	0.66148E+01
	125.00	-0.97752E+00	0.98569E-02	-0.61263E+03	0.60831E+01
2	13.42	-0.20391E-03	-0.32438E+01	0.12114E+05	0.66148E+01
	124.78	-0.97193E+00	-0.17850E+00	-0.61656E+03	0.60697E+01
3	26.80	0.32050E-03	-0.32619E+01	0.11412E+05	0.65476E+01
	124.11	-0.95544E+00	-0.36686E+00	-0.62252E+03	0.59991E+01
4	40.15	0.22378E-02	-0.33134E+01	0.10245E+05	0.65476E+01
	123.01	-0.92875E+00	-0.59785E+00	-0.63282E+03	0.59297E+01
5	53.46	0.60939E-02	-0.33973E+01	0.86070E+04	0.65476E+01
	121.47	-0.89301E+00	-0.88055E+00	-0.64811E+03	0.57859E+01
6	66.71	0.12261E-01	-0.35510E+01	0.64919E+04	0.65476E+01

	119.48	-0.84991E+00	-0.12019E+01	-0.66901E+03	0.55127E+01
7	79.89	0.20821E-01	-0.37990E+01	0.38812E+04	0.63124E+01
	117.06	-0.80195E+00	-0.14665E+01	-0.69545E+03	0.44639E+01
8	92.98	0.31513E-01	-0.41078E+01	0.74162E+03	0.48019E+01
	114.21	-0.75200E+00	-0.15997E+01	-0.72624E+03	0.00000E+00
9	105.97	0.43875E-01	-0.46009E+01	-0.29663E+04	0.30685E+01
	110.92	-0.70214E+00	-0.18062E+01	-0.76114E+03	0.51202E+01
10	118.85	0.56922E-01	-0.53294E+01	-0.73169E+04	0.30809E+01
	107.21	-0.65550E+00	-0.18395E+01	-0.79977E+03	0.65776E+01
11	131.59	0.69364E-01	-0.61293E+01	-0.12433E+05	0.34674E+01
	103.08	-0.61585E+00	-0.17713E+01	-0.84090E+03	0.80039E+01
12	144.19	0.80483E-01	-0.69136E+01	-0.18464E+05	0.40809E+01
	98.53	-0.58400E+00	-0.18143E+01	-0.88544E+03	0.10113E+02
13	156.64	0.90199E-01	-0.79135E+01	-0.25569E+05	0.49117E+01
	93.56	-0.55878E+00	-0.17918E+01	-0.93494E+03	0.13077E+02
14	168.91	0.98882E-01	-0.89555E+01	-0.33970E+05	0.64703E+01
	88.19	-0.53827E+00	-0.73681E+01	-0.11010E+04	0.18665E+02
15	171.76	0.11569E+00	-0.47682E+01	-0.29824E+05	0.47460E+01
	75.95	-0.53402E+00	-0.23804E+01	-0.12499E+04	0.12463E+02
16	173.47	0.12727E+00	-0.48196E+01	-0.25021E+05	0.37441E+01
	63.50	-0.53198E+00	-0.22771E+01	-0.12616E+04	0.91076E+01
17	174.00	0.12926E+00	-0.44083E+01	-0.19506E+05	0.33970E+01
	50.94	-0.53137E+00	-0.12977E+01	-0.12727E+04	0.79042E+01
18	174.00	0.11453E+00	-0.30947E+01	-0.12257E+05	0.34814E+01
	33.96	-0.53060E+00	-0.25318E+00	-0.12919E+04	0.73567E+01
19	174.00	0.85856E-01	-0.15809E+01	-0.59005E+04	0.41094E+01
	16.98	-0.52993E+00	-0.38657E+00	-0.13150E+04	0.57414E+01
20	174.00	0.51776E-01	-0.67208E-01	0.23078E-09	0.61687E+01
	0.00	-0.52948E+00	-0.51997E+00	-0.13393E+04	0.00000E+00

SHEAR FORCE DIAGNOSTCS FOR CONCRETE-GROUP 1, LOAD STEP 9
-- V-factor is coefficient of sqrt(PFPC) equal to capacity.
-- Shear depth "d" is negative if measured from outer wall.
-- Stirrup load is excess shear force above capacity.

NODE	EQUIVALENT V-factor	SHEAR CAPACITY lbs/inch	APPLIED SHEAR lbs/inch	APPLIED/ CAPACITY ratio	SHEAR DEPTH-d inches	STIRRUP LOAD lbs/inch
1	2.68	1726.73	0.18	0.000	8.00	0.00
2	2.68	1727.06	34.99	0.020	8.00	0.00
3	2.68	1727.56	69.76	0.040	8.00	0.00
4	2.68	1728.43	104.68	0.061	8.00	0.00
5	2.68	1729.71	140.04	0.081	8.00	0.00
6	2.68	1731.46	176.36	0.102	8.00	0.00
7	3.76	2443.88	214.58	0.088	8.06	0.00

8	4.50	2923.16	255.52	0.087	8.06	0.00
9	4.50	2764.55	300.73	0.109	-7.63	0.00
10	2.99	1970.57	353.28	0.179	-8.19	0.00
11	2.23	1774.48	415.96	0.234	-9.88	0.00
12	1.92	1966.08	490.17	0.249	-12.69	0.00
13	1.82	2447.09	578.64	0.236	-16.69	0.00
14	1.41	2790.65	148.47	0.053	-24.56	0.00
15	1.65	2116.31	-356.08	0.168	-15.88	0.00
16	1.99	1782.81	-410.39	0.230	-11.13	0.00
17	2.19	1685.02	-432.79	0.257	-9.56	0.00
18	2.31	1780.48	-400.63	0.225	-9.56	0.00
19	3.90	3007.03	-360.94	0.120	-9.56	0.00
20	4.50	3625.40	-334.09	0.092	10.00	0.00

STRESS AND STRAIN MEASURES FOR CONCRETE-GROUP 1, LOAD STEP 9

NODE	MAXIMUM COMPRESSION psi	AVERAGE SHEAR psi	RADIAL TENSION psi	INNER-WALL STRAIN in/in	OUTER-WALL STRAIN in/in
1	-1111.86	0.02	4.12	0.3904E-03	-0.2350E-03
2	-1093.51	4.50	4.03	0.3823E-03	-0.2311E-03
3	-1042.67	8.97	3.74	0.3554E-03	-0.2203E-03
4	-948.14	13.45	3.31	0.3165E-03	-0.2004E-03
5	-812.79	18.00	2.70	0.2595E-03	-0.1718E-03
6	-636.51	22.66	1.91	0.1875E-03	-0.1345E-03
7	-372.83	27.36	0.76	0.8078E-04	-0.7879E-04
8	-100.06	32.57	0.00	-0.5365E-05	-0.2114E-04
9	-411.92	38.34	0.00	-0.8705E-04	0.1105E-03
10	-755.77	42.03	0.00	-0.1597E-03	0.2858E-03
11	-894.35	41.21	0.00	-0.1890E-03	0.3796E-03
12	-870.72	37.98	0.00	-0.1840E-03	0.4015E-03
13	-779.69	34.23	0.00	-0.1648E-03	0.3879E-03
14	-590.74	5.99	0.00	-0.1248E-03	0.3120E-03
15	-996.30	-22.12	0.00	-0.2105E-03	0.4799E-03
16	-1443.86	-36.18	0.00	-0.3051E-03	0.6541E-03
17	-1464.90	-44.25	0.00	-0.3096E-03	0.6267E-03
18	-1040.70	-40.96	0.00	-0.2199E-03	0.3743E-03
19	-563.42	-36.90	0.00	-0.1191E-03	0.1284E-03
20	-100.34	-34.16	0.00	-0.2120E-04	-0.2120E-04

STEEL STRESS AND CRACK WIDTHS FOR CONCRETE-GROUP 1, LOAD STEP 9
NOTE: CRACK WIDTH IS REDUCED TO SERVICE-LOAD LEVEL.
ALL OTHER RESPONSES ARE AT FACTORED LOAD LEVEL.

NODE	INNER CAGE psi	OUTER CAGE psi	MAX STRESS TO YIELD ratio	CRACK WIDTH inches
1	8456.22	-2629.66	0.1409	0.00000
2	8273.78	-2599.35	0.1379	0.00000
3	7655.62	-2549.64	0.1276	0.00000
4	6790.75	-2370.54	0.1132	0.00000
5	5522.23	-2123.24	0.0920	0.00000
6	3923.54	-1784.93	0.0654	0.00000
7	1563.78	-1278.98	0.0261	0.00000
8	-270.92	-552.03	0.0092	0.00000
9	-1522.61	1997.22	0.0333	0.00000

10	-2417.07	5850.88	0.0975	0.00000
11	-3079.50	8510.44	0.1418	0.00000
12	-3396.60	9786.75	0.1631	0.00000
13	-3408.86	10116.45	0.1686	0.00000
14	-2947.09	8684.80	0.1447	0.00000
15	-4306.45	12364.09	0.2061	0.00000
16	-5215.52	15352.39	0.2559	0.00000
17	-4892.24	13911.10	0.2319	0.00000
18	-3852.38	8080.95	0.1347	0.00000
19	-2479.92	2489.86	0.0415	0.00000
20	-675.75	-675.75	0.0113	0.00000

ASSESSMENT SUMMARY CONCRETE-GROUP 1, LOAD-STEP 9

LRFD SUMMARY EVALUATION FOR GROUP 1, LOAD STEP 9

DESIGN-CRITERION	CONTROL NODE	FACTORED DEMAND	FACTORED CAPACITY	RATIO VALUE
STEEL YIELDING (psi)	16	15352.4	60000.0	0.256
CONCRETE CRUSHING (psi)	17	1464.9	4875.0	0.300
SHEAR FAILURE (lbs/in)	17	432.8	1516.5	0.285
RADIAL-TENSION FAIL (psi)	1	4.1	69.6	0.059

LRFD SERVICE-LOAD PERFORMANCE MEASURES FOR GROUP 1, LOAD STEP 9

NODE NUMBER FOR MAXIMUM CRACK WIDTH 1

MAXIMUM CRACK WIDTH AT SERVICE LOAD (inches) 0.00000

LRFD RATIO: MAX-CRACK-WIDTH / ALLOWABLE 0.00

SPAN LENGTH FOR AUXILIARY EQUATIONS (inches)...... 348.00

+ +

FINITE ELEMENT OUTPUT FOR LOAD STEP 13

+ +

CONCRETE, FACTORED-EVALUATION FOR GROUP 1, LOAD-STEP 13

STRUCTURAL RESPONSES OF CONCRETE-GROUP 1, LOAD-STEP 13
COORDINATES, DISPLACEMENTS AND CRACK DEPTHS ARE INCHES

28x10HL93c1Mod.out

Y-BAR IS "NEUTRAL AXIS" LOCATION FROM INTERIOR, INCHES
PRESSURES ARE LB/IN**2
MOMENTS ARE IN-LB/IN
THRUST AND SHEAR ARE LB/IN

LOCAL NODE	X-COORD. Y-COORD.	X-DISP. Y-DISP.	N-PRES. S-PRES.	MOMENT THRUST	Y-BAR CRACK DEPTH
1	0.00	0.00000E+00	-0.42227E+02	0.51871E+05	0.65127E+01
	125.00	-0.19929E+01	-0.16779E+02	-0.10845E+04	0.63920E+01
2	13.42	-0.19813E-03	-0.26375E+02	0.48094E+05	0.65127E+01
	124.78	-0.19695E+01	-0.10450E+02	-0.12397E+04	0.63568E+01
3	26.80	0.24516E-02	-0.10524E+02	0.39975E+05	0.65704E+01
	124.11	-0.19027E+01	-0.41211E+01	-0.13562E+04	0.63010E+01
4	40.15	0.10266E-01	-0.25847E+01	0.30412E+05	0.66148E+01
	123.01	-0.17999E+01	-0.95393E+00	-0.14138E+04	0.61953E+01
5	53.46	0.24666E-01	-0.12726E+01	0.20854E+05	0.65476E+01
	121.47	-0.16700E+01	-0.43774E+00	-0.14479E+04	0.59702E+01
6	66.71	0.46161E-01	-0.45960E+01	0.11554E+05	0.65476E+01
	119.48	-0.15220E+01	-0.17762E+01	-0.14877E+04	0.54790E+01
7	79.89	0.74358E-01	-0.37492E+01	0.19341E+04	0.56601E+01
	117.06	-0.13652E+01	-0.14469E+01	-0.15350E+04	0.14352E+01
8	92.98	0.10794E+00	-0.45779E+01	-0.78358E+04	0.24151E+01
	114.21	-0.12089E+01	-0.17877E+01	-0.15833E+04	0.64273E+01
9	105.97	0.14442E+00	-0.54107E+01	-0.17879E+05	0.29481E+01
	110.92	-0.10622E+01	-0.21299E+01	-0.16373E+04	0.64952E+01
10	118.85	0.18003E+00	-0.64108E+01	-0.28322E+05	0.30809E+01
	107.21	-0.93562E+00	-0.25380E+01	-0.16978E+04	0.70832E+01
11	131.59	0.21154E+00	-0.72541E+01	-0.39327E+05	0.34674E+01
	103.08	-0.83574E+00	-0.28833E+01	-0.17656E+04	0.83621E+01
12	144.19	0.23798E+00	-0.80642E+01	-0.51040E+05	0.40809E+01
	98.53	-0.76032E+00	-0.32180E+01	-0.18410E+04	0.10445E+02
13	156.64	0.26006E+00	-0.96821E+01	-0.63612E+05	0.45666E+01
	93.56	-0.70314E+00	-0.38820E+01	-0.19274E+04	0.13481E+02
14	168.91	0.27925E+00	-0.11551E+02	-0.77357E+05	0.57315E+01
	88.19	-0.65775E+00	-0.64673E+01	-0.20732E+04	0.19517E+02
15	171.76	0.31608E+00	-0.90277E+01	-0.66458E+05	0.47460E+01
	75.95	-0.64852E+00	-0.24343E+01	-0.21557E+04	0.12799E+02
16	173.47	0.34123E+00	-0.10980E+02	-0.54512E+05	0.37441E+01
	63.50	-0.64431E+00	-0.26820E+01	-0.21179E+04	0.93149E+01
17	174.00	0.34545E+00	-0.12050E+02	-0.41817E+05	0.33970E+01
	50.94	-0.64325E+00	-0.98578E-01	-0.20845E+04	0.81073E+01
18	174.00	0.31370E+00	-0.75241E+01	-0.26207E+05	0.34814E+01
	33.96	-0.64199E+00	0.26689E+01	-0.20586E+04	0.77081E+01

19	174.00	0.25159E+00	-0.23484E+01	-0.12764E+05	0.36437E+01
	16.98	-0.64089E+00	0.61644E+00	-0.20484E+04	0.67560E+01
20	174.00	0.17744E+00	0.28274E+01	0.35811E-09	0.61687E+01
	0.00	-0.64018E+00	-0.14360E+01	-0.20556E+04	0.00000E+00

SHEAR FORCE DIAGNOSTCS FOR CONCRETE-GROUP 1, LOAD STEP 13
-- V-factor is coefficient of sqrt(PFPC) equal to capacity.
-- Shear depth "d" is negative if measured from outer wall.
-- Stirrup load is excess shear force above capacity.

NODE	EQUIVALENT V-factor	SHEAR CAPACITY lbs/inch	APPLIED SHEAR lbs/inch	APPLIED/ CAPACITY ratio	SHEAR DEPTH-d inches	STIRRUP LOAD lbs/inch
1	2.74	1766.27	119.23	0.068	8.00	0.00
2	2.76	1779.26	443.72	0.249	8.00	0.00
3	2.77	1789.02	659.86	0.369	8.00	0.00
4	2.78	1793.85	713.54	0.398	8.00	0.00
5	2.79	1796.70	703.68	0.392	8.00	0.00
6	4.01	2587.87	706.03	0.273	8.00	0.00
7	4.50	2923.16	723.58	0.248	8.06	0.00
8	3.74	2298.36	739.34	0.322	-7.63	0.00
9	2.80	1723.08	764.48	0.444	-7.63	0.00
10	2.48	1636.88	800.42	0.489	-8.19	0.00
11	2.18	1736.50	847.77	0.488	-9.88	0.00
12	1.88	1922.76	906.20	0.471	-12.69	0.00
13	1.65	2214.26	982.06	0.444	-16.69	0.00
14	1.43	2839.89	79.05	0.028	-24.56	0.00
15	1.69	2166.92	-909.00	0.419	-15.88	0.00
16	2.05	1836.58	-979.99	0.534	-11.13	0.00
17	2.26	1739.15	-964.59	0.555	-9.56	0.00
18	2.31	1783.49	-855.53	0.480	-9.56	0.00
19	3.77	2904.97	-771.72	0.266	-9.56	0.00
20	4.50	3625.40	-731.84	0.202	10.00	0.00

STRESS AND STRAIN MEASURES FOR CONCRETE-GROUP 1, LOAD STEP 13

NODE	MAXIMUM COMPRESSION psi	AVERAGE SHEAR psi	RADIAL TENSION psi	INNER-WALL STRAIN in/in	OUTER-WALL STRAIN in/in
1	-3903.64	15.32	18.30	0.1712E-02	-0.9509E-03
2	-3746.59	57.02	16.80	0.1576E-02	-0.8874E-03
3	-3386.30	84.80	13.77	0.1291E-02	-0.7419E-03
4	-2726.44	91.70	10.20	0.9644E-03	-0.5761E-03
5	-1953.30	90.43	6.64	0.6363E-03	-0.4128E-03
6	-1188.03	90.73	3.28	0.3264E-03	-0.2511E-03
7	-325.26	92.24	0.00	0.1143E-04	-0.6873E-04
8	-945.06	94.25	0.00	-0.1997E-03	0.3807E-03
9	-1981.04	97.46	0.00	-0.4186E-03	0.7903E-03
10	-2672.88	95.22	0.00	-0.5648E-03	0.1160E-02
11	-2683.63	83.99	0.00	-0.5671E-03	0.1231E-02
12	-2322.55	70.21	0.00	-0.4908E-03	0.1128E-02
13	-1879.02	58.09	0.00	-0.3971E-03	0.9824E-03
14	-1284.21	3.19	0.00	-0.2714E-03	0.7438E-03
15	-2144.74	-56.48	0.00	-0.4532E-03	0.1085E-02

16	-3050.37	-86.39	0.00	-0.6446E-03	0.1445E-02
17	-3033.96	-98.62	0.00	-0.6411E-03	0.1366E-02
18	-2107.09	-87.47	0.00	-0.4453E-03	0.8276E-03
19	-1145.41	-78.90	0.00	-0.2420E-03	0.3347E-03
20	-154.02	-74.82	0.00	-0.3255E-04	-0.3255E-04

STEEL STRESS AND CRACK WIDTHS FOR CONCRETE-GROUP 1, LOAD STEP 13
NOTE: CRACK WIDTH IS REDUCED TO SERVICE-LOAD LEVEL.
ALL OTHER RESPONSES ARE AT FACTORED LOAD LEVEL.

NODE	INNER CAGE psi	OUTER CAGE psi	MAX STRESS TO YIELD ratio	CRACK WIDTH inches
1	37593.75	-9615.82	0.6266	0.00698
2	34519.62	-9146.36	0.5753	0.00604
3	28178.53	-7852.50	0.4696	0.00407
4	20915.48	-6393.63	0.3486	0.00180
5	13592.05	-5004.80	0.2265	0.00000
6	6720.30	-3515.25	0.1120	0.00000
7	-143.38	-1571.56	0.0262	0.00000
8	-2687.96	7652.60	0.1275	0.00000
9	-5683.68	15854.00	0.2642	0.00000
10	-7655.55	24347.17	0.4058	0.00041
11	-8762.39	27897.43	0.4650	0.00090
12	-8820.87	27622.34	0.4604	0.00000
13	-8056.70	25703.12	0.4284	0.00000
14	-6251.73	20783.50	0.3464	0.00000
15	-9088.83	28058.41	0.4676	0.00000
16	-10720.84	34090.39	0.5682	0.00281
17	-9770.44	30541.56	0.5090	0.00238
18	-7428.83	18135.68	0.3023	0.00000
19	-4650.11	6933.20	0.1156	0.00000
20	-1037.18	-1037.18	0.0173	0.00000

ASSESSMENT SUMMARY CONCRETE-GROUP 1, LOAD-STEP 13

LRFD SUMMARY EVALUATION FOR GROUP 1, LOAD STEP 13

DESIGN-CRITERION	CONTROL NODE	FACTORED DEMAND	FACTORED CAPACITY	RATIO VALUE
STEEL YIELDING (psi)	1	37593.8	60000.0	0.627
CONCRETE CRUSHING (psi)	1	3903.6	4875.0	0.801
SHEAR FAILURE (lbs/in)	17	964.6	1565.2	0.616
RADIAL-TENSION FAIL (psi)	1	18.3	69.6	0.263

LRFD SERVICE-LOAD PERFORMANCE MEASURES FOR GROUP 1, LOAD STEP 13

NODE NUMBER FOR MAXIMUM CRACK WIDTH 1

```
MAXIMUM CRACK WIDTH AT SERVICE LOAD (inches) .....    0.00698

LRFD RATIO: MAX-CRACK-WIDTH / ALLOWABLE ..........       0.70

SPAN LENGTH FOR AUXILIARY EQUATIONS (inches)......     348.00



* * * * NORMAL EXIT FROM CANDE * * * *
```

28x10HL93c2Mod.out

```
*** WELCOME TO CANDE-2013(version 3/1/2013) ***

MASTER CONTROL AND PIPE-TYPE DATA FOR PROBLEM #  1

        USER TITLE: 28x10

        EXECUTION MODE ..................   ANALYS

        SOLUTION LEVEL ..................  #2 AUTO

        METHODOLOGY (LRFD OR SERVICE) ...     LRFD

        NUMBER OF PIPE-ELEMENT GROUPS ....       1

        MAXIMUM ITERATIONS PER STEP ......      30


        CULVERT PIPE-TYPE ............... CONCRETE

        CANNED MESH CODE # ..............        3

        NUMBER OF BEAM ELEMENTS .........       19

        CONCRETE MATERIAL PROPERTIES ARE AS FOLLOWS

             COMPRESSION STRENGTH (psi)..........       6500.000

             ELASTIC YOUNGS MODULUS (psi)........    4595487.000

             POISSON RATIO ......................          0.170

             CONCRETE DENSITY (pcf) .............        150.000

             INITIAL TENSILE CRACKING STRAIN.....       0.000010

             INITIAL COMPRESSION YIELD STRAIN....       0.000687

             INITIAL COMPRESSION CRUSH STRAIN ...       0.002000

             SHEAR STRENGTH MODEL (NSHEAR) # ...          1
             (VARIABLE STRENGTH MODEL PRINTED IN OUTPUT)

             CONCRETE CRACK-WIDTH MODEL NAME.....   HEGER-McGRATH
             (DRIVEN BY TENSILE STRAIN IN STEEL)

        STEEL REINFORCEMENT MATERIAL PROPERTIES

             TYPE OF STEEL CAGES (RSHAPE) .......     ARBIT

             STEEL YIELD STRENGTH (psi)..........      60000.000

             STEEL ELASTIC MODULUS (psi).........   29000000.000
```

28x10HL93c2Mod.out

STEEL POISSON RATIO 0.300000

STEEL YIELDING STRAIN 0.001883

NONLINEAR MODELING CODE (1,2,3) 3

STEEL-BASED CRACKWIDTH PREDICTION PARAMETERS
REBAR SPACING INNER ROW (SLI), (in) 4.00
REBAR SPACING OUTER ROW (SLO), (in) 4.00
NUMBER OF STEEL LAYERS FOR INNER CAGE 1
NUMBER OF STEEL LAYERS FOR OUTER CAGE 1
HEGER-MCGRATH CODE NUMBER FOR STEEL TYPE.. 3

WALL THICKNESS, REBAR AREAS AND COVER DEPTHS

WALL-THICK	INNER-REBAR	OUTER-REBAR	INNER-COVER	OUTER COVER
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1100	0.1500	2.0000	2.4375
10.6250	0.1100	0.1500	2.0000	2.4375
12.3130	0.1100	0.1500	2.0000	2.4375
15.1250	0.1100	0.1500	2.0000	2.4375
19.1250	0.1100	0.1500	2.0000	2.4375
27.0000	0.1100	0.1500	2.0000	2.4375
18.3130	0.1100	0.1500	2.0000	2.4375
13.5630	0.1100	0.1500	2.0000	2.4375
12.0000	0.1100	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375

LRFD RESISTANCE FACTORS FOR STRENGTH-LIMIT STATES
AND CRACK-WIDTH LIMIT AT SERVICE LOAD

YIELDING OF REINFORCEMENT STEEL 1.000

CRUSHING OF CONCRETE OUTER FIBER..... 0.750

SHEARING FAILURE OF CONCRETE 0.900

SPLITTING OF CONCRETE IN RADIAL TENSION 0.900

ALLOWABLE CRACKWIDTH SERVICE LOAD (inch).... 0.010

LARGE DEFORMATION/BUCKLING CODE, IBUCK = 0
IBUCK=0, MEANS SMALL DEFORMATION THEORY FOR GROUP
AND NO BUCKLING PREDICTION.

28x10HL93c2Mod.out

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


 REVIEW SYSTEM INPUT DATA


 LEVEL-2 DATA FOR ARCH-TYPE CANNED MESH


    *** MESH PARAMETERS ***
     TYPE OF MESH ------------------------------------- TREN
     DEPTH OF TRENCH ABOVE FOOTING LEVEL (FT) ---------   12.42
     WIDTH OF TRENCH AT FOOTING LEVEL (FT) ------------    5.00
     SLOPE OF TRENCH WALL (H/V) -----------------------    0.00
     MESH SPACING PARAMETER ---------------------------    1.00
     TOTAL SOIL HEIGHT ABOVE CROWN (FT) ---------------    2.00
     MESH HEIGHT ABOVE CROWN (FT) ----------------------    2.00
     SOIL DENSITY ABOVE MESH (PCF) --------------------  140.00
     NUMBER OF ELEMENT LAYERS ABOVE CROWN -------------    3


*** ARCH PARAMETERS ***
     CENTERLINE RISE OF ARCH (IN) ---------------------  125.00
     BOTTOM HALF SPAN OF ARCH (IN) --------------------  174.00
     SIDE RISE OF ARCH ABOVE FOOTING (IN) -------------   50.94
     FOOTING DEPTH (IN) -------------------------------   24.00
     OUTSIDE FOOTING WIDTH (IN) -----------------------   30.00
     INSIDE FOOTING WIDTH (IN) ------------------------   30.00
     NUMBER OF ARCH SEGMENTS DEFINED ------------------    3

*** CURVED TOP SEGMENT ***
     RADIUS (IN) --------------------------------------  405.88
     CENTRAL ANGLE (DEG) ------------------------------   24.59
     SEGMENT ARC LENGTH (IN) --------------------------  174.19
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------   13

*** CURVED CORNER SEGMENT ***
     RADIUS (IN) --------------------------------------  133.94
     CENTRAL ANGLE (DEG) ------------------------------   16.14
     SEGMENT ARC LENGTH (IN) --------------------------   37.73
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------    3

*** STRAIGHT SIDE SEGMENT ***
     DEFLECTION ANGLE (DEG) ---------------------------   90.00
     SEGMENT LENGTH (IN) ------------------------------   50.94
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------    3

 FINITE ELEMENT INPUT CONTROLS (PREP)


THE DATA TO BE RUN IS ENTITLED ...

New Level 2 arch mesh

PRINT AND PLOT CONTROL CODES ...
  PRINT CONTROL FOR MESH DATA------------    1
  PLOT FILE CONTROL MESH & RESULS--------    3
  PRINT FINITE ELEMENT RESULTS ----------    1
  INPUT DATA CHECK CODE------------------    0
```

28x10HL93c2Mod.out

```
KEY NUMBERS DESCRIBING MESH ...
  THE NUMBER OF LOAD STEPS IS------------   13
  TOTAL NUMBER OF NODES IS---------------  244
  TOTAL NUMBER OF ELEMENTS IS------------  209
  TOTAL NUMBER OF BEAM ELEMENTS IS-------   19
  MAX NUMBER OF BOUNDARY CONDITIONS IS---   36


 EXTENDED LEVEL-2: CHANGES TO CANNED MESH

          * NUMBER OF NODES TO BE CHANGED -------      0 *
          * NUMBER OF ELEMENTS TO BE CHANGED ----      0 *
          * ADDITIONAL BOUNDARY CONDITIONS ------     31 *


 * * * BOUNDARY CONDITIONS * * *
  (FORCES = LBS; DISPLACEMENTS = INCHES; ROTATIONS = DEGREES)

  BOUNDARY      LOAD      X-FORCE     OR      Y-FORCE     OR      X-Y ROTATION
BEAM ROTATIONAL
     NODE       STEP      X-DISPLACEMENT      Y-DISPLACEMENT
BOUNDARY CONDITIONS

      229        10    F =   0.0000E+00    F =  -0.1785E+03      0.0000E+00
     F
      229        11    F =   0.0000E+00    F =  -0.1785E+03      0.0000E+00
     F
      229        12    F =   0.0000E+00    F =  -0.1785E+03      0.0000E+00
     F
      229        13    F =   0.0000E+00    F =  -0.1785E+03      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        11    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        12    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        13    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      224        10    F =   0.0000E+00    F =  -0.4800E+01      0.0000E+00
     F
      225        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      226        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      227        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      228        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
```

```
F
 231        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
F
 232        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
F
 233        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
F
 224         9    F =   0.0000E+00    F =  -0.2188E+01      0.0000E+00
F
 225         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 226         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 227         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 228         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 229         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 230         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 231         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 232         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 233         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 234         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 235         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 236         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F

* * * * * COMPLETED MESH GENERATION  * * * * *

New Level 2 arch mesh

CALCULATED KEY NUMBERS ...
  THE NUMBER OF DATA ERRORS IS-----------     0
  THE NUMBER OF SOIL MATERIALS IS--------     3
  THE NUMBER OF PIPE-TYPE GROUPS IS------     1
  THE NUMBER OF INTERFACE MATERIALS IS---    19
  BAND WIDTH ESTIMATE (MAX)--------------    88


* * * * MESH DATA HAS BEEN SAVED ON UNIT 14 * * * *


 BEAM-NODE SEQUENCE NUMBERS FOR EACH GROUP


    BEAM-ELEMENT GROUP NUMBER =    1

     BEAM-NODE       MESH-NODE      CONNECTED-GROUP-ELEMENTS
     SEQUENCE        NUMBER         FOREWARD-#     BACKWARD-#
         1             198              1              0
         2             194              2              1
         3             190              3              2
         4             167              4              3
```

5	164	5	4
6	161	6	5
7	158	7	6
8	138	8	7
9	136	9	8
10	134	10	9
11	132	11	10
12	130	12	11
13	128	13	12
14	118	14	13
15	115	15	14
16	109	16	15
17	103	17	16
18	97	18	17
19	91	19	18
20	80	0	19

```
MATERIAL DESCRIPTION FOR SOILS AND INTERFACE
(ALL DENSITY UNITS ARE pcf, ALL MODULUS UNITS ARE psi)

   PROPERTIES FOR MATERIAL  1   ********in site

        DENSITY =    0.14000E+03

        YOUNGS MODULUS= 0.5000E+04
        POISSONS RATIO= 0.3500E+00
        CONFINED MOD.= 0.8025E+04
        LATERAL COEFF.= 0.5385E+00

   PROPERTIES FOR MATERIAL  2   ********Footing

        DENSITY =    0.15000E+03

        YOUNGS MODULUS= 0.3122E+07
        POISSONS RATIO= 0.1700E+00
        CONFINED MOD.= 0.3356E+07
        LATERAL COEFF.= 0.2048E+00

   PROPERTIES FOR MATERIAL  3   ********SW95

        DENSITY =    0.14000E+03

   CONTROLS FOR DUNCAN SOIL MODEL
   WITH SELIG HYPERBOLIC BULK MODULUS FORMULATION

         LRFD STRESS CONTROL..........        0

         ENTERING ELEMENT RATIO.......      0.5000


   HYPERBOLIC STRESS-STRAIN PARAMETERS


         SOIL CLASSIFICATION ............SW95
```

COHESION INTERCEPT C 0.0000

FRICTION ANGLE PHIO (DEG)..... 48.0000

10-FOLD REDUCTION IN PHIO(DEG).. 8.0000

SCALED MODULUS NUMBER ZK 950.0000

MODULUS EXPONENT ZN 0.6000

FAILURE RATIO RF 0.7000

INIT. BULK MODULUS NUMBER BI.... 74.8000

ULT. VOLUMETRIC STRAIN EU 0.0200

INTERFACE ELEMENT MATERIAL-GROUP PROPERTIES

MAT. NO.	NORMAL-ANGLE	COEF-FRICTION	TENSILE-RUPTURE	INITIAL-GAP
1	90.00	0.40000	10.00000	0.00000
2	88.11	0.40000	10.00000	0.00000
3	86.22	0.40000	10.00000	0.00000
4	84.32	0.40000	10.00000	0.00000
5	82.43	0.40000	10.00000	0.00000
6	80.54	0.40000	10.00000	0.00000
7	78.65	0.40000	10.00000	0.00000
8	76.76	0.40000	10.00000	0.00000
9	74.87	0.40000	10.00000	0.00000
10	72.97	0.40000	10.00000	0.00000
11	71.08	0.40000	10.00000	0.00000
12	69.19	0.40000	10.00000	0.00000
13	67.30	0.40000	10.00000	0.00000
14	65.41	0.40000	10.00000	0.00000
15	10.46	0.40000	10.00000	0.00000
16	5.11	0.40000	10.00000	0.00000
17	0.00	0.40000	10.00000	0.00000
18	0.00	0.40000	10.00000	0.00000
19	0.00	0.40000	10.00000	0.00000

LRFD TOTAL LOAD FACTORS PER LOAD STEP

LOAD STEP	LOAD FACTOR	USER COMMENT
1	1.310	Factor for load step #1
2	0.857	Factor for load step #2
3	0.857	Factor for load step #3
4	0.857	Factor for load step #4
5	1.365	Factor for load step #5
6	1.365	Factor for load step #6
7	1.365	Factor for load step #7

8	1.365	Factor for load step #8
9	1.500	Factor for load step #9
10	1.750	Factor for load step #10
11	1.750	Factor for load step #11
12	1.750	Factor for load step #12
13	1.750	Factor for load step #13

+

SOLUTION OUTPUT RESULTS

+

FINITE ELEMENT OUTPUT FOR LOAD STEP 13

+

CONCRETE, FACTORED-EVALUATION FOR GROUP 1, LOAD-STEP 13

STRUCTURAL RESPONSES OF CONCRETE-GROUP 1, LOAD-STEP 13
COORDINATES, DISPLACEMENTS AND CRACK DEPTHS ARE INCHES
Y-BAR IS "NEUTRAL AXIS" LOCATION FROM INTERIOR, INCHES
PRESSURES ARE LB/IN**2
MOMENTS ARE IN-LB/IN
THRUST AND SHEAR ARE LB/IN

LOCAL NODE	X-COORD. Y-COORD.	X-DISP. Y-DISP.	N-PRES. S-PRES.	MOMENT THRUST	Y-BAR CRACK DEPTH
1	0.00	0.00000E+00	-0.45446E+01	0.25897E+05	0.66148E+01
	125.00	-0.19540E+01	-0.27618E-02	-0.16736E+04	0.60469E+01
2	13.42	-0.65547E-03	-0.40387E+01	0.25812E+05	0.66148E+01
	124.78	-0.19422E+01	-0.31834E+00	-0.16786E+04	0.60432E+01
3	26.80	0.24241E-03	-0.35327E+01	0.25586E+05	0.66148E+01
	124.11	-0.19070E+01	-0.63392E+00	-0.16861E+04	0.60361E+01
4	40.15	0.42303E-02	-0.34111E+01	0.25317E+05	0.66148E+01
	123.01	-0.18487E+01	0.73640E-01	-0.16914E+04	0.60275E+01
5	53.46	0.12816E-01	-0.89893E+01	0.25029E+05	0.66148E+01
	121.47	-0.17677E+01	0.34488E+01	-0.16705E+04	0.60211E+01
6	66.71	0.27446E-01	-0.20199E+02	0.23712E+05	0.65476E+01
	119.48	-0.16650E+01	0.59533E+01	-0.16137E+04	0.59927E+01

7	79.89	0.49218E-01	-0.24907E+02	0.19329E+05	0.65930E+01
	117.06	-0.15428E+01	-0.31556E+00	-0.15894E+04	0.58955E+01
8	92.98	0.78363E-01	-0.26808E+02	0.11021E+05	0.63124E+01
	114.21	-0.14065E+01	-0.10723E+02	-0.16865E+04	0.50161E+01
9	105.97	0.11400E+00	-0.31108E+02	-0.15064E+04	0.38329E+01
	110.92	-0.12630E+01	-0.12392E+02	-0.18756E+04	0.24069E+01
10	118.85	0.15337E+00	-0.57179E+01	-0.18941E+05	0.30809E+01
	107.21	-0.11231E+01	-0.22624E+01	-0.20173E+04	0.67427E+01
11	131.59	0.19200E+00	-0.72184E+01	-0.36674E+05	0.34674E+01
	103.08	-0.10008E+01	-0.28702E+01	-0.20998E+04	0.82429E+01
12	144.19	0.22701E+00	-0.69346E+01	-0.54960E+05	0.40809E+01
	98.53	-0.90120E+00	-0.27679E+01	-0.21881E+04	0.10399E+02
13	156.64	0.25800E+00	-0.83661E+01	-0.73748E+05	0.45666E+01
	93.56	-0.82129E+00	-0.33567E+01	-0.22833E+04	0.13487E+02
14	168.91	0.28611E+00	-0.89267E+01	-0.93314E+05	0.57315E+01
	88.19	-0.75515E+00	-0.94729E+01	-0.25442E+04	0.19543E+02
15	171.76	0.34188E+00	-0.68764E+01	-0.81455E+05	0.47460E+01
	75.95	-0.74132E+00	-0.32278E+01	-0.27376E+04	0.12798E+02
16	173.47	0.38351E+00	-0.10619E+02	-0.67530E+05	0.38703E+01
	63.50	-0.73463E+00	-0.36045E+01	-0.26963E+04	0.92976E+01
17	174.00	0.39918E+00	-0.13271E+02	-0.52115E+05	0.35078E+01
	50.94	-0.73284E+00	-0.59958E+00	-0.26590E+04	0.80936E+01
18	174.00	0.37350E+00	-0.91209E+01	-0.32725E+05	0.34814E+01
	33.96	-0.73124E+00	0.26647E+01	-0.26322E+04	0.77092E+01
19	174.00	0.30974E+00	-0.27672E+01	-0.15963E+05	0.36437E+01
	16.98	-0.72980E+00	0.78369E+00	-0.26206E+04	0.67834E+01
20	174.00	0.23086E+00	0.35864E+01	-0.12574E-09	0.61687E+01
	0.00	-0.72888E+00	-0.10973E+01	-0.26250E+04	0.00000E+00

SHEAR FORCE DIAGNOSTCS FOR CONCRETE-GROUP 1, LOAD STEP 13
-- V-factor is coefficient of sqrt(PFPC) equal to capacity.
-- Shear depth "d" is negative if measured from outer wall.
-- Stirrup load is excess shear force above capacity.

NODE	EQUIVALENT V-factor	SHEAR CAPACITY lbs/inch	APPLIED SHEAR lbs/inch	APPLIED/ CAPACITY ratio	SHEAR DEPTH-d inches	STIRRUP LOAD lbs/inch
1	2.81	1815.61	1.14	0.001	8.00	0.00
2	2.82	1816.03	11.61	0.006	8.00	0.00
3	2.82	1816.66	18.44	0.010	8.00	0.00
4	2.82	1817.11	20.78	0.011	8.00	0.00
5	2.81	1815.35	59.89	0.033	8.00	0.00
6	2.81	1810.60	212.73	0.117	8.00	0.00
7	2.79	1810.46	473.61	0.262	8.06	0.00
8	4.50	2922.61	777.49	0.266	8.06	0.00
9	4.50	2764.55	1118.12	0.404	-7.63	0.00

10	3.97	2619.85	1312.38	0.501	-8.19	0.00
11	2.47	1970.19	1344.06	0.682	-9.88	0.00
12	1.91	1953.69	1383.43	0.708	-12.69	0.00
13	1.67	2250.11	1431.30	0.636	-16.69	0.00
14	1.45	2863.75	258.08	0.090	-24.56	0.00
15	1.72	2199.43	-1025.96	0.466	-15.88	0.00
16	2.09	1872.91	-1166.92	0.623	-11.13	0.00
17	2.31	1777.45	-1184.08	0.666	-9.56	0.00
18	2.36	1821.45	-1064.58	0.584	-9.56	0.00
19	3.86	2975.89	-963.65	0.324	-9.56	0.00
20	4.50	3466.79	-916.66	0.264	-9.56	0.00

STRESS AND STRAIN MEASURES FOR CONCRETE-GROUP 1, LOAD STEP 13

NODE	MAXIMUM COMPRESSION psi	AVERAGE SHEAR psi	RADIAL TENSION psi	INNER-WALL STRAIN in/in	OUTER-WALL STRAIN in/in
1	-2407.91	0.15	8.39	0.8036E-03	-0.5088E-03
2	-2401.99	1.49	8.36	0.8005E-03	-0.5076E-03
3	-2383.81	2.37	8.30	0.7923E-03	-0.5037E-03
4	-2361.22	2.67	8.17	0.7823E-03	-0.4990E-03
5	-2328.87	7.70	8.06	0.7699E-03	-0.4921E-03
6	-2210.73	27.34	7.54	0.7236E-03	-0.4672E-03
7	-1774.70	60.38	5.74	0.5547E-03	-0.3750E-03
8	-1024.91	99.12	2.26	0.2352E-03	-0.2166E-03
9	-1024.91	142.54	0.00	-0.9266E-04	0.2913E-04
10	-1946.89	156.12	0.00	-0.4114E-03	0.7419E-03
11	-2576.22	133.15	0.00	-0.5444E-03	0.1133E-02
12	-2529.54	107.19	0.00	-0.5345E-03	0.1208E-02
13	-2187.36	84.66	0.00	-0.4622E-03	0.1140E-02
14	-1556.32	10.41	0.00	-0.3289E-03	0.8981E-03
15	-2640.15	-63.75	0.00	-0.5579E-03	0.1328E-02
16	-3553.45	-102.86	0.00	-0.8094E-03	0.1796E-02
17	-3554.20	-121.06	0.00	-0.8097E-03	0.1708E-02
18	-2643.16	-108.84	0.00	-0.5585E-03	0.1031E-02
19	-1451.98	-98.52	0.00	-0.3068E-03	0.4220E-03
20	-196.68	-93.72	0.00	-0.4156E-04	-0.4156E-04

STEEL STRESS AND CRACK WIDTHS FOR CONCRETE-GROUP 1, LOAD STEP 13
NOTE: CRACK WIDTH IS REDUCED TO SERVICE-LOAD LEVEL.
ALL OTHER RESPONSES ARE AT FACTORED LOAD LEVEL.

NODE	INNER CAGE psi	OUTER CAGE psi	MAX STRESS TO YIELD ratio	CRACK WIDTH inches
1	17244.97	-6020.48	0.2874	0.00083
2	17173.32	-6014.58	0.2862	0.00079
3	16988.58	-5985.74	0.2831	0.00068
4	16763.05	-5948.71	0.2794	0.00054
5	16490.39	-5880.29	0.2748	0.00035
6	15469.60	-5638.15	0.2578	0.00000
7	11787.56	-4774.87	0.1965	0.00000
8	4633.84	-3414.62	0.0772	0.00000
9	-2181.51	-11.79	0.0364	0.00000
10	-6192.54	15210.91	0.2535	0.00000
11	-8667.14	25519.38	0.4253	0.00013

12	-9691.06	29550.66	0.4925	0.00001
13	-9392.17	29809.42	0.4968	0.00000
14	-7584.13	25092.04	0.4182	0.00000
15	-11216.77	34313.42	0.5719	0.00000
16	-13549.99	42315.65	0.7053	0.00547
17	-12429.55	38140.42	0.6357	0.00483
18	-9354.46	22579.08	0.3763	0.00000
19	-5907.01	8730.25	0.1455	0.00000
20	-1324.46	-1324.46	0.0221	0.00000

ASSESSMENT SUMMARY CONCRETE-GROUP 1, LOAD-STEP 13

LRFD SUMMARY EVALUATION FOR GROUP 1, LOAD STEP 13

DESIGN-CRITERION	CONTROL NODE	FACTORED DEMAND	FACTORED CAPACITY	RATIO VALUE
STEEL YIELDING (psi)	16	42315.6	60000.0	0.705
CONCRETE CRUSHING (psi)	17	3554.2	4875.0	0.729
SHEAR FAILURE (lbs/in)	12	1383.4	1758.3	0.787
RADIAL-TENSION FAIL (psi)	1	8.4	69.6	0.121

LRFD SERVICE-LOAD PERFORMANCE MEASURES FOR GROUP 1, LOAD STEP 13

NODE NUMBER FOR MAXIMUM CRACK WIDTH 16

MAXIMUM CRACK WIDTH AT SERVICE LOAD (inches) 0.00547

LRFD RATIO: MAX-CRACK-WIDTH / ALLOWABLE 0.55

SPAN LENGTH FOR AUXILIARY EQUATIONS (inches)..... 348.00

* * * * NORMAL EXIT FROM CANDE * * * *

28x10HL93c3Mod.out

```
*** WELCOME TO CANDE-2013(version 3/1/2013) ***

MASTER CONTROL AND PIPE-TYPE DATA FOR PROBLEM #  1

        USER TITLE: 28x10

        EXECUTION MODE ..................   ANALYS

        SOLUTION LEVEL ..................  #2 AUTO

        METHODOLOGY (LRFD OR SERVICE) ...     LRFD

        NUMBER OF PIPE-ELEMENT GROUPS ....       1

        MAXIMUM ITERATIONS PER STEP ......      30


        CULVERT PIPE-TYPE ............... CONCRETE

        CANNED MESH CODE # ..............        3

        NUMBER OF BEAM ELEMENTS .........       19

        CONCRETE MATERIAL PROPERTIES ARE AS FOLLOWS

             COMPRESSION STRENGTH (psi)..........       6500.000

             ELASTIC YOUNGS MODULUS (psi)........    4595487.000

             POISSON RATIO ......................          0.170

             CONCRETE DENSITY (pcf) .............        150.000

             INITIAL TENSILE CRACKING STRAIN.....       0.000010

             INITIAL COMPRESSION YIELD STRAIN....       0.000687

             INITIAL COMPRESSION CRUSH STRAIN ...       0.002000

             SHEAR STRENGTH MODEL (NSHEAR) # ...          1
             (VARIABLE STRENGTH MODEL PRINTED IN OUTPUT)

             CONCRETE CRACK-WIDTH MODEL NAME.....   HEGER-McGRATH
             (DRIVEN BY TENSILE STRAIN IN STEEL)

        STEEL REINFORCEMENT MATERIAL PROPERTIES

             TYPE OF STEEL CAGES (RSHAPE) .......     ARBIT

             STEEL YIELD STRENGTH (psi)..........      60000.000

             STEEL ELASTIC MODULUS (psi).........   29000000.000
```

STEEL POISSON RATIO 0.300000

STEEL YIELDING STRAIN 0.001883

NONLINEAR MODELING CODE (1,2,3) 3

STEEL-BASED CRACKWIDTH PREDICTION PARAMETERS

REBAR SPACING INNER ROW (SLI), (in)	4.00
REBAR SPACING OUTER ROW (SLO), (in)	4.00
NUMBER OF STEEL LAYERS FOR INNER CAGE	1
NUMBER OF STEEL LAYERS FOR OUTER CAGE	1
HEGER-MCGRATH CODE NUMBER FOR STEEL TYPE..	3

WALL THICKNESS, REBAR AREAS AND COVER DEPTHS

WALL-THICK	INNER-REBAR	OUTER-REBAR	INNER-COVER	OUTER COVER
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1100	0.1500	2.0000	2.4375
10.6250	0.1100	0.1500	2.0000	2.4375
12.3130	0.1100	0.1500	2.0000	2.4375
15.1250	0.1100	0.1500	2.0000	2.4375
19.1250	0.1100	0.1500	2.0000	2.4375
27.0000	0.1100	0.1500	2.0000	2.4375
18.3130	0.1100	0.1500	2.0000	2.4375
13.5630	0.1100	0.1500	2.0000	2.4375
12.0000	0.1100	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375

LRFD RESISTANCE FACTORS FOR STRENGTH-LIMIT STATES
AND CRACK-WIDTH LIMIT AT SERVICE LOAD

YIELDING OF REINFORCEMENT STEEL	1.000
CRUSHING OF CONCRETE OUTER FIBER.....	0.750
SHEARING FAILURE OF CONCRETE	0.900
SPLITTING OF CONCRETE IN RADIAL TENSION	0.900
ALLOWABLE CRACKWIDTH SERVICE LOAD (inch)....	0.010

LARGE DEFORMATION/BUCKLING CODE, IBUCK = 0
IBUCK=0, MEANS SMALL DEFORMATION THEORY FOR GROUP
AND NO BUCKLING PREDICTION.

28x10HL93c3Mod.out

- -

REVIEW SYSTEM INPUT DATA

LEVEL-2 DATA FOR ARCH-TYPE CANNED MESH

```
    *** MESH PARAMETERS ***
     TYPE OF MESH ------------------------------------- TREN
     DEPTH OF TRENCH ABOVE FOOTING LEVEL (FT) ---------   12.42
     WIDTH OF TRENCH AT FOOTING LEVEL (FT) ------------    5.00
     SLOPE OF TRENCH WALL (H/V) -----------------------    0.00
     MESH SPACING PARAMETER ---------------------------    1.00
     TOTAL SOIL HEIGHT ABOVE CROWN (FT) ---------------    2.00
     MESH HEIGHT ABOVE CROWN (FT) ---------------------    2.00
     SOIL DENSITY ABOVE MESH (PCF) --------------------  140.00
     NUMBER OF ELEMENT LAYERS ABOVE CROWN -------------    3


*** ARCH PARAMETERS ***
     CENTERLINE RISE OF ARCH (IN) ---------------------  125.00
     BOTTOM HALF SPAN OF ARCH (IN) --------------------  174.00
     SIDE RISE OF ARCH ABOVE FOOTING (IN) -------------   50.94
     FOOTING DEPTH (IN) -------------------------------   24.00
     OUTSIDE FOOTING WIDTH (IN) -----------------------   30.00
     INSIDE FOOTING WIDTH (IN) ------------------------   30.00
     NUMBER OF ARCH SEGMENTS DEFINED ------------------    3

*** CURVED TOP SEGMENT ***
     RADIUS (IN) --------------------------------------  405.88
     CENTRAL ANGLE (DEG) ------------------------------   24.59
     SEGMENT ARC LENGTH (IN) --------------------------  174.19
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------   13

*** CURVED CORNER SEGMENT ***
     RADIUS (IN) --------------------------------------  133.94
     CENTRAL ANGLE (DEG) ------------------------------   16.14
     SEGMENT ARC LENGTH (IN) --------------------------   37.73
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------    3

*** STRAIGHT SIDE SEGMENT ***
     DEFLECTION ANGLE (DEG) ---------------------------   90.00
     SEGMENT LENGTH (IN) ------------------------------   50.94
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------    3
```

FINITE ELEMENT INPUT CONTROLS (PREP)

THE DATA TO BE RUN IS ENTITLED ...

New Level 2 arch mesh

```
PRINT AND PLOT CONTROL CODES ...
  PRINT CONTROL FOR MESH DATA------------     1
  PLOT FILE CONTROL MESH & RESULS--------     3
  PRINT FINITE ELEMENT RESULTS ----------     1
  INPUT DATA CHECK CODE------------------     0
```

28x10HL93c3Mod.out

```
KEY NUMBERS DESCRIBING MESH ...
  THE NUMBER OF LOAD STEPS IS------------   13
  TOTAL NUMBER OF NODES IS---------------  244
  TOTAL NUMBER OF ELEMENTS IS------------  209
  TOTAL NUMBER OF BEAM ELEMENTS IS-------   19
  MAX NUMBER OF BOUNDARY CONDITIONS IS---   36


 EXTENDED LEVEL-2: CHANGES TO CANNED MESH

          * NUMBER OF NODES TO BE CHANGED -------      0 *
          * NUMBER OF ELEMENTS TO BE CHANGED ----      0 *
          * ADDITIONAL BOUNDARY CONDITIONS ------     31 *


 * * * BOUNDARY CONDITIONS * * *
  (FORCES = LBS; DISPLACEMENTS = INCHES; ROTATIONS = DEGREES)

  BOUNDARY      LOAD      X-FORCE     OR      Y-FORCE     OR      X-Y ROTATION
BEAM ROTATIONAL
     NODE       STEP      X-DISPLACEMENT      Y-DISPLACEMENT
BOUNDARY CONDITIONS

      225        10    F =   0.0000E+00    F =  -0.1395E+03      0.0000E+00
     F
      225        11    F =   0.0000E+00    F =  -0.1395E+03      0.0000E+00
     F
      225        12    F =   0.0000E+00    F =  -0.1395E+03      0.0000E+00
     F
      225        13    F =   0.0000E+00    F =  -0.1395E+03      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        11    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        12    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        13    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      224        10    F =   0.0000E+00    F =  -0.4800E+01      0.0000E+00
     F
      225        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      226        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      227        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      228        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
```

28x10HL93c3Mod.out

```
F
 231        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
F
 232        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
F
 233        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
F
 224         9    F =   0.0000E+00    F =  -0.2188E+01      0.0000E+00
F
 225         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 226         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 227         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 228         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 229         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 230         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 231         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 232         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 233         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 234         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 235         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 236         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F

* * * * * COMPLETED MESH GENERATION  * * * * *

New Level 2 arch mesh

CALCULATED KEY NUMBERS ...
  THE NUMBER OF DATA ERRORS IS-----------    0
  THE NUMBER OF SOIL MATERIALS IS--------    3
  THE NUMBER OF PIPE-TYPE GROUPS IS------    1
  THE NUMBER OF INTERFACE MATERIALS IS---   19
  BAND WIDTH ESTIMATE (MAX)--------------   88


* * * * MESH DATA HAS BEEN SAVED ON UNIT 14 * * * *


 BEAM-NODE SEQUENCE NUMBERS FOR EACH GROUP


    BEAM-ELEMENT GROUP NUMBER =    1

     BEAM-NODE       MESH-NODE      CONNECTED-GROUP-ELEMENTS
     SEQUENCE        NUMBER         FOREWARD-#     BACKWARD-#
         1             198              1              0
         2             194              2              1
         3             190              3              2
         4             167              4              3
```

5	164	5	4
6	161	6	5
7	158	7	6
8	138	8	7
9	136	9	8
10	134	10	9
11	132	11	10
12	130	12	11
13	128	13	12
14	118	14	13
15	115	15	14
16	109	16	15
17	103	17	16
18	97	18	17
19	91	19	18
20	80	0	19

```
MATERIAL DESCRIPTION FOR SOILS AND INTERFACE
(ALL DENSITY UNITS ARE pcf, ALL MODULUS UNITS ARE psi)

   PROPERTIES FOR MATERIAL  1   ********in site

        DENSITY =    0.14000E+03

        YOUNGS MODULUS= 0.5000E+04
        POISSONS RATIO= 0.3500E+00
        CONFINED MOD.= 0.8025E+04
        LATERAL COEFF.= 0.5385E+00

   PROPERTIES FOR MATERIAL  2   ********Footing

        DENSITY =    0.15000E+03

        YOUNGS MODULUS= 0.3122E+07
        POISSONS RATIO= 0.1700E+00
        CONFINED MOD.= 0.3356E+07
        LATERAL COEFF.= 0.2048E+00

   PROPERTIES FOR MATERIAL  3   ********SW95

        DENSITY =    0.14000E+03

   CONTROLS FOR DUNCAN SOIL MODEL
   WITH SELIG HYPERBOLIC BULK MODULUS FORMULATION

         LRFD STRESS CONTROL..........       0

         ENTERING ELEMENT RATIO.......      0.5000


   HYPERBOLIC STRESS-STRAIN PARAMETERS


         SOIL CLASSIFICATION ............SW95
```

COHESION INTERCEPT C 0.0000

FRICTION ANGLE PHIO (DEG)..... 48.0000

10-FOLD REDUCTION IN PHIO(DEG).. 8.0000

SCALED MODULUS NUMBER ZK 950.0000

MODULUS EXPONENT ZN 0.6000

FAILURE RATIO RF 0.7000

INIT. BULK MODULUS NUMBER BI.... 74.8000

ULT. VOLUMETRIC STRAIN EU 0.0200

INTERFACE ELEMENT MATERIAL-GROUP PROPERTIES

MAT. NO.	NORMAL-ANGLE	COEF-FRICTION	TENSILE-RUPTURE	INITIAL-GAP
1	90.00	0.40000	10.00000	0.00000
2	88.11	0.40000	10.00000	0.00000
3	86.22	0.40000	10.00000	0.00000
4	84.32	0.40000	10.00000	0.00000
5	82.43	0.40000	10.00000	0.00000
6	80.54	0.40000	10.00000	0.00000
7	78.65	0.40000	10.00000	0.00000
8	76.76	0.40000	10.00000	0.00000
9	74.87	0.40000	10.00000	0.00000
10	72.97	0.40000	10.00000	0.00000
11	71.08	0.40000	10.00000	0.00000
12	69.19	0.40000	10.00000	0.00000
13	67.30	0.40000	10.00000	0.00000
14	65.41	0.40000	10.00000	0.00000
15	10.46	0.40000	10.00000	0.00000
16	5.11	0.40000	10.00000	0.00000
17	0.00	0.40000	10.00000	0.00000
18	0.00	0.40000	10.00000	0.00000
19	0.00	0.40000	10.00000	0.00000

LRFD TOTAL LOAD FACTORS PER LOAD STEP

LOAD STEP	LOAD FACTOR	USER COMMENT
1	1.310	Factor for load step #1
2	0.857	Factor for load step #2
3	0.857	Factor for load step #3
4	0.857	Factor for load step #4
5	1.365	Factor for load step #5
6	1.365	Factor for load step #6
7	1.365	Factor for load step #7

28x10HL93c3Mod.out

8	1.365	Factor for load step #8
9	1.500	Factor for load step #9
10	1.750	Factor for load step #10
11	1.750	Factor for load step #11
12	1.750	Factor for load step #12
13	1.750	Factor for load step #13

\+ +

SOLUTION OUTPUT RESULTS

\+ +

FINITE ELEMENT OUTPUT FOR LOAD STEP 13

\+ +

CONCRETE, FACTORED-EVALUATION FOR GROUP 1, LOAD-STEP 13

STRUCTURAL RESPONSES OF CONCRETE-GROUP 1, LOAD-STEP 13
COORDINATES, DISPLACEMENTS AND CRACK DEPTHS ARE INCHES
Y-BAR IS "NEUTRAL AXIS" LOCATION FROM INTERIOR, INCHES
PRESSURES ARE LB/IN**2
MOMENTS ARE IN-LB/IN
THRUST AND SHEAR ARE LB/IN

LOCAL NODE	X-COORD. Y-COORD.	X-DISP. Y-DISP.	N-PRES. S-PRES.	MOMENT THRUST	Y-BAR CRACK DEPTH
1	0.00	0.00000E+00	-0.48397E+02	0.64227E+05	0.61714E+01
	125.00	-0.24762E+01	0.90407E+01	-0.15882E+04	0.62773E+01
2	13.42	-0.33206E-03	-0.35573E+02	0.61856E+05	0.62003E+01
	124.78	-0.24460E+01	0.13480E-01	-0.16014E+04	0.62799E+01
3	26.80	0.31854E-02	-0.22749E+02	0.53649E+05	0.63944E+01
	124.11	-0.23583E+01	-0.90137E+01	-0.16811E+04	0.62860E+01
4	40.15	0.13610E-01	-0.13820E+02	0.41946E+05	0.65369E+01
	123.01	-0.22216E+01	-0.54467E+01	-0.18068E+04	0.62260E+01
5	53.46	0.32920E-01	-0.54519E+01	0.28405E+05	0.66148E+01
	121.47	-0.20474E+01	-0.21096E+01	-0.18912E+04	0.60313E+01
6	66.71	0.61796E-01	-0.26586E+00	0.14569E+05	0.65476E+01
	119.48	-0.18485E+01	-0.44301E-01	-0.19408E+04	0.54864E+01

7	79.89	0.99611E-01	-0.42318E+01	0.13890E+04	0.51548E+01
	117.06	-0.16385E+01	-0.16402E+01	-0.19871E+04	0.00000E+00
8	92.98	0.14448E+00	-0.39540E+01	-0.11827E+05	0.24151E+01
	114.21	-0.14296E+01	-0.15383E+01	-0.20434E+04	0.67478E+01
9	105.97	0.19277E+00	-0.56710E+01	-0.25001E+05	0.29481E+01
	110.92	-0.12351E+01	-0.22341E+01	-0.21042E+04	0.65573E+01
10	118.85	0.23927E+00	-0.68182E+01	-0.38414E+05	0.31316E+01
	107.21	-0.10699E+01	-0.27010E+01	-0.21739E+04	0.71127E+01
11	131.59	0.27998E+00	-0.77748E+01	-0.52253E+05	0.35229E+01
	103.08	-0.94090E+00	-0.30917E+01	-0.22511E+04	0.83864E+01
12	144.19	0.31379E+00	-0.87125E+01	-0.66678E+05	0.40809E+01
	98.53	-0.84447E+00	-0.34776E+01	-0.23364E+04	0.10481E+02
13	156.64	0.34178E+00	-0.10448E+02	-0.81859E+05	0.45666E+01
	93.56	-0.77190E+00	-0.31967E+01	-0.24264E+04	0.13538E+02
14	168.91	0.36601E+00	-0.13030E+02	-0.98130E+05	0.57315E+01
	88.19	-0.71451E+00	-0.45367E+01	-0.25397E+04	0.19631E+02
15	171.76	0.41248E+00	-0.11564E+02	-0.84001E+05	0.44372E+01
	75.95	-0.70287E+00	-0.24287E+01	-0.25790E+04	0.12907E+02
16	173.47	0.44416E+00	-0.14008E+02	-0.68730E+05	0.38703E+01
	63.50	-0.69760E+00	-0.25247E+01	-0.25156E+04	0.93351E+01
17	174.00	0.44928E+00	-0.14773E+02	-0.52718E+05	0.35078E+01
	50.94	-0.69633E+00	0.63880E+00	-0.24580E+04	0.81324E+01
18	174.00	0.40875E+00	-0.94685E+01	-0.33043E+05	0.34814E+01
	33.96	-0.69486E+00	0.34640E+01	-0.24146E+04	0.77773E+01
19	174.00	0.32974E+00	-0.29470E+01	-0.16096E+05	0.36437E+01
	16.98	-0.69355E+00	0.85583E+00	-0.23956E+04	0.69164E+01
20	174.00	0.23548E+00	0.35745E+01	0.47817E-09	0.61687E+01
	0.00	-0.69272E+00	-0.17524E+01	-0.23988E+04	0.00000E+00

SHEAR FORCE DIAGNOSTCS FOR CONCRETE-GROUP 1, LOAD STEP 13
-- V-factor is coefficient of sqrt(PFPC) equal to capacity.
-- Shear depth "d" is negative if measured from outer wall.
-- Stirrup load is excess shear force above capacity.

NODE	EQUIVALENT V-factor	SHEAR CAPACITY lbs/inch	APPLIED SHEAR lbs/inch	APPLIED/ CAPACITY ratio	SHEAR DEPTH-d inches	STIRRUP LOAD lbs/inch
1	2.80	1808.46	-41.30	0.023	8.00	0.00
2	2.81	1809.57	394.61	0.218	8.00	0.00
3	2.82	1816.24	743.00	0.409	8.00	0.00
4	2.83	1826.77	942.02	0.516	8.00	0.00
5	2.84	1833.84	1021.63	0.557	8.00	0.00
6	4.44	2865.52	1008.16	0.352	8.00	0.00
7	4.50	2923.16	985.01	0.337	8.06	0.00
8	3.48	2142.23	984.77	0.460	-7.63	0.00

9	2.69	1653.12	992.16	0.600	-7.63	0.00
10	2.53	1670.83	1017.00	0.609	-8.19	0.00
11	2.22	1768.45	1054.70	0.596	-9.88	0.00
12	1.91	1952.44	1104.76	0.566	-12.69	0.00
13	1.67	2241.76	1173.69	0.524	-16.69	0.00
14	1.45	2863.51	44.71	0.016	-24.56	0.00
15	1.71	2190.57	-1169.85	0.534	-15.88	0.00
16	2.08	1861.56	-1244.15	0.668	-11.13	0.00
17	2.29	1764.05	-1216.19	0.689	-9.56	0.00
18	2.33	1797.65	-1078.42	0.600	-9.56	0.00
19	3.78	2913.56	-973.02	0.334	-9.56	0.00
20	4.50	3625.40	-922.98	0.255	10.00	0.00

STRESS AND STRAIN MEASURES FOR CONCRETE-GROUP 1, LOAD STEP 13

NODE	MAXIMUM COMPRESSION psi	AVERAGE SHEAR psi	RADIAL TENSION psi	INNER-WALL STRAIN in/in	OUTER-WALL STRAIN in/in
1	-4665.18	-5.31	22.76	0.2149E-02	-0.1259E-02
2	-4533.62	50.71	21.84	0.2062E-02	-0.1205E-02
3	-4081.14	95.49	18.71	0.1758E-02	-0.1023E-02
4	-3523.24	121.06	14.20	0.1342E-02	-0.7972E-03
5	-2644.77	131.29	9.15	0.8746E-03	-0.5589E-03
6	-1510.77	129.56	4.11	0.4102E-03	-0.3192E-03
7	-346.87	125.57	0.00	-0.1340E-05	-0.7330E-04
8	-1511.46	125.54	0.00	-0.3194E-03	0.6804E-03
9	-2746.85	126.48	0.00	-0.5805E-03	0.1114E-02
10	-3448.15	120.98	0.00	-0.7668E-03	0.1583E-02
11	-3418.86	104.48	0.00	-0.7550E-03	0.1644E-02
12	-3024.59	85.60	0.00	-0.6391E-03	0.1475E-02
13	-2411.79	69.42	0.00	-0.5096E-03	0.1269E-02
14	-1619.95	1.80	0.00	-0.3423E-03	0.9486E-03
15	-2676.60	-72.69	0.00	-0.5656E-03	0.1384E-02
16	-3572.04	-109.67	0.00	-0.8169E-03	0.1836E-02
17	-3557.52	-124.34	0.00	-0.8110E-03	0.1736E-02
18	-2626.21	-110.25	0.00	-0.5550E-03	0.1051E-02
19	-1426.44	-99.48	0.00	-0.3014E-03	0.4337E-03
20	-179.72	-94.36	0.00	-0.3798E-04	-0.3798E-04

STEEL STRESS AND CRACK WIDTHS FOR CONCRETE-GROUP 1, LOAD STEP 13
NOTE: CRACK WIDTH IS REDUCED TO SERVICE-LOAD LEVEL.
ALL OTHER RESPONSES ARE AT FACTORED LOAD LEVEL.

NODE	INNER CAGE psi	OUTER CAGE psi	MAX STRESS TO YIELD ratio	CRACK WIDTH inches
1	46769.01	-13638.69	0.7795	0.00975
2	44880.29	-13036.21	0.7480	0.00917
3	38294.53	-10991.51	0.6382	0.00712
4	29123.23	-8790.76	0.4854	0.00428
5	18734.12	-6675.83	0.3122	0.00103
6	8423.36	-4507.54	0.1404	0.00000
7	-498.48	-1780.45	0.0297	0.00000
8	-3845.83	13966.47	0.2328	0.00000
9	-7763.12	22431.33	0.3739	0.00000
10	-10340.65	33272.52	0.5545	0.00329

11	-11643.04	37254.73	0.6209	0.00392
12	-11459.07	36149.67	0.6025	0.00214
13	-10313.61	33219.77	0.5537	0.00000
14	-7861.75	26516.50	0.4419	0.00000
15	-11238.29	35845.32	0.5974	0.00048
16	-13567.36	43310.87	0.7218	0.00579
17	-12316.02	38844.79	0.6474	0.00506
18	-9158.10	23086.28	0.3848	0.00000
19	-5701.39	9062.97	0.1510	0.00000
20	-1210.31	-1210.31	0.0202	0.00000

ASSESSMENT SUMMARY CONCRETE-GROUP 1, LOAD-STEP 13

LRFD SUMMARY EVALUATION FOR GROUP 1, LOAD STEP 13

DESIGN-CRITERION	CONTROL NODE	FACTORED DEMAND	FACTORED CAPACITY	RATIO VALUE
STEEL YIELDING (psi)	1	46769.0	60000.0	0.779
CONCRETE CRUSHING (psi)	1	4665.2	4875.0	0.957
SHEAR FAILURE (lbs/in)	17	1216.2	1587.6	0.766
RADIAL-TENSION FAIL (psi)	1	22.8	69.6	0.327

LRFD SERVICE-LOAD PERFORMANCE MEASURES FOR GROUP 1, LOAD STEP 13

NODE NUMBER FOR MAXIMUM CRACK WIDTH 1

MAXIMUM CRACK WIDTH AT SERVICE LOAD (inches) 0.00975

LRFD RATIO: MAX-CRACK-WIDTH / ALLOWABLE 0.98

SPAN LENGTH FOR AUXILIARY EQUATIONS (inches)..... 348.00

* * * * NORMAL EXIT FROM CANDE * * * *

28x10HL93c4Mod.out

```
*** WELCOME TO CANDE-2013(version 3/1/2013) ***

MASTER CONTROL AND PIPE-TYPE DATA FOR PROBLEM #  1

        USER TITLE: 28x10

        EXECUTION MODE ..................   ANALYS

        SOLUTION LEVEL ..................  #2 AUTO

        METHODOLOGY (LRFD OR SERVICE) ...     LRFD

        NUMBER OF PIPE-ELEMENT GROUPS ....       1

        MAXIMUM ITERATIONS PER STEP ......      30


        CULVERT PIPE-TYPE ............... CONCRETE

        CANNED MESH CODE # ..............        3

        NUMBER OF BEAM ELEMENTS .........       19

        CONCRETE MATERIAL PROPERTIES ARE AS FOLLOWS

             COMPRESSION STRENGTH (psi)..........       6500.000

             ELASTIC YOUNGS MODULUS (psi)........    4595487.000

             POISSON RATIO ......................          0.170

             CONCRETE DENSITY (pcf) .............        150.000

             INITIAL TENSILE CRACKING STRAIN.....       0.000010

             INITIAL COMPRESSION YIELD STRAIN....       0.000687

             INITIAL COMPRESSION CRUSH STRAIN ...       0.002000

             SHEAR STRENGTH MODEL (NSHEAR) # ...          1
             (VARIABLE STRENGTH MODEL PRINTED IN OUTPUT)

             CONCRETE CRACK-WIDTH MODEL NAME.....   HEGER-McGRATH
             (DRIVEN BY TENSILE STRAIN IN STEEL)

        STEEL REINFORCEMENT MATERIAL PROPERTIES

             TYPE OF STEEL CAGES (RSHAPE) .......     ARBIT

             STEEL YIELD STRENGTH (psi)..........      60000.000

             STEEL ELASTIC MODULUS (psi).........   29000000.000
```

STEEL POISSON RATIO 0.300000

STEEL YIELDING STRAIN 0.001883

NONLINEAR MODELING CODE (1,2,3) 3

STEEL-BASED CRACKWIDTH PREDICTION PARAMETERS

REBAR SPACING INNER ROW (SLI), (in)	4.00
REBAR SPACING OUTER ROW (SLO), (in)	4.00
NUMBER OF STEEL LAYERS FOR INNER CAGE	1
NUMBER OF STEEL LAYERS FOR OUTER CAGE	1
HEGER-MCGRATH CODE NUMBER FOR STEEL TYPE..	3

WALL THICKNESS, REBAR AREAS AND COVER DEPTHS

WALL-THICK	INNER-REBAR	OUTER-REBAR	INNER-COVER	OUTER COVER
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1100	0.1500	2.0000	2.4375
10.6250	0.1100	0.1500	2.0000	2.4375
12.3130	0.1100	0.1500	2.0000	2.4375
15.1250	0.1100	0.1500	2.0000	2.4375
19.1250	0.1100	0.1500	2.0000	2.4375
27.0000	0.1100	0.1500	2.0000	2.4375
18.3130	0.1100	0.1500	2.0000	2.4375
13.5630	0.1100	0.1500	2.0000	2.4375
12.0000	0.1100	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375

LRFD RESISTANCE FACTORS FOR STRENGTH-LIMIT STATES
AND CRACK-WIDTH LIMIT AT SERVICE LOAD

YIELDING OF REINFORCEMENT STEEL	1.000
CRUSHING OF CONCRETE OUTER FIBER.....	0.750
SHEARING FAILURE OF CONCRETE	0.900
SPLITTING OF CONCRETE IN RADIAL TENSION	0.900
ALLOWABLE CRACKWIDTH SERVICE LOAD (inch)....	0.010

LARGE DEFORMATION/BUCKLING CODE, IBUCK = 0
IBUCK=0, MEANS SMALL DEFORMATION THEORY FOR GROUP
AND NO BUCKLING PREDICTION.

28x10HL93c4Mod.out

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


 REVIEW SYSTEM INPUT DATA


 LEVEL-2 DATA FOR ARCH-TYPE CANNED MESH


    *** MESH PARAMETERS ***
     TYPE OF MESH ------------------------------------- TREN
     DEPTH OF TRENCH ABOVE FOOTING LEVEL (FT) ---------   12.42
     WIDTH OF TRENCH AT FOOTING LEVEL (FT) ------------    5.00
     SLOPE OF TRENCH WALL (H/V) -----------------------    0.00
     MESH SPACING PARAMETER ---------------------------    1.00
     TOTAL SOIL HEIGHT ABOVE CROWN (FT) ---------------    2.00
     MESH HEIGHT ABOVE CROWN (FT) ----------------------    2.00
     SOIL DENSITY ABOVE MESH (PCF) --------------------  140.00
     NUMBER OF ELEMENT LAYERS ABOVE CROWN -------------    3


*** ARCH PARAMETERS ***
     CENTERLINE RISE OF ARCH (IN) ----------------------  125.00
     BOTTOM HALF SPAN OF ARCH (IN) ---------------------  174.00
     SIDE RISE OF ARCH ABOVE FOOTING (IN) -------------   50.94
     FOOTING DEPTH (IN) --------------------------------   24.00
     OUTSIDE FOOTING WIDTH (IN) ------------------------   30.00
     INSIDE FOOTING WIDTH (IN) -------------------------   30.00
     NUMBER OF ARCH SEGMENTS DEFINED -------------------    3

*** CURVED TOP SEGMENT ***
     RADIUS (IN) ---------------------------------------  405.88
     CENTRAL ANGLE (DEG) -------------------------------   24.59
     SEGMENT ARC LENGTH (IN) ---------------------------  174.19
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------   13

*** CURVED CORNER SEGMENT ***
     RADIUS (IN) ---------------------------------------  133.94
     CENTRAL ANGLE (DEG) -------------------------------   16.14
     SEGMENT ARC LENGTH (IN) ---------------------------   37.73
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

*** STRAIGHT SIDE SEGMENT ***
     DEFLECTION ANGLE (DEG) ----------------------------   90.00
     SEGMENT LENGTH (IN) -------------------------------   50.94
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

 FINITE ELEMENT INPUT CONTROLS (PREP)


THE DATA TO BE RUN IS ENTITLED ...

New Level 2 arch mesh

PRINT AND PLOT CONTROL CODES ...
  PRINT CONTROL FOR MESH DATA------------    1
  PLOT FILE CONTROL MESH & RESULS--------    3
  PRINT FINITE ELEMENT RESULTS ----------    1
  INPUT DATA CHECK CODE------------------    0
```

28x10HL93c4Mod.out

```
KEY NUMBERS DESCRIBING MESH ...
  THE NUMBER OF LOAD STEPS IS------------   13
  TOTAL NUMBER OF NODES IS---------------  244
  TOTAL NUMBER OF ELEMENTS IS------------  209
  TOTAL NUMBER OF BEAM ELEMENTS IS-------   19
  MAX NUMBER OF BOUNDARY CONDITIONS IS---   36



 EXTENDED LEVEL-2: CHANGES TO CANNED MESH

          * NUMBER OF NODES TO BE CHANGED -------      0 *
          * NUMBER OF ELEMENTS TO BE CHANGED ----      0 *
          * ADDITIONAL BOUNDARY CONDITIONS ------     31 *



* * * BOUNDARY CONDITIONS * * *
 (FORCES = LBS; DISPLACEMENTS = INCHES; ROTATIONS = DEGREES)

 BOUNDARY      LOAD      X-FORCE     OR      Y-FORCE     OR      X-Y ROTATION
BEAM ROTATIONAL
     NODE      STEP      X-DISPLACEMENT      Y-DISPLACEMENT
BOUNDARY CONDITIONS

      228        10    F =   0.0000E+00    F =  -0.1395E+03      0.0000E+00
     F
      228        11    F =   0.0000E+00    F =  -0.1395E+03      0.0000E+00
     F
      228        12    F =   0.0000E+00    F =  -0.1395E+03      0.0000E+00
     F
      228        13    F =   0.0000E+00    F =  -0.1395E+03      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =  -0.1395E+03      0.0000E+00
     F
      230        11    F =   0.0000E+00    F =  -0.1395E+03      0.0000E+00
     F
      230        12    F =   0.0000E+00    F =  -0.1395E+03      0.0000E+00
     F
      230        13    F =   0.0000E+00    F =  -0.1395E+03      0.0000E+00
     F
      224        10    F =   0.0000E+00    F =  -0.4800E+01      0.0000E+00
     F
      225        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      226        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      227        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      228        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
```

```
F
 231        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
F
 232        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
F
 233        10    F =   0.0000E+00    F =  -0.9600E+01      0.0000E+00
F
 224         9    F =   0.0000E+00    F =  -0.2188E+01      0.0000E+00
F
 225         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 226         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 227         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 228         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 229         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 230         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 231         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 232         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 233         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 234         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 235         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 236         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F

* * * * * COMPLETED MESH GENERATION  * * * * *

New Level 2 arch mesh

CALCULATED KEY NUMBERS ...
  THE NUMBER OF DATA ERRORS IS-----------    0
  THE NUMBER OF SOIL MATERIALS IS--------    3
  THE NUMBER OF PIPE-TYPE GROUPS IS------    1
  THE NUMBER OF INTERFACE MATERIALS IS---   19
  BAND WIDTH ESTIMATE (MAX)--------------   88


* * * * MESH DATA HAS BEEN SAVED ON UNIT 14 * * * *


 BEAM-NODE SEQUENCE NUMBERS FOR EACH GROUP


    BEAM-ELEMENT GROUP NUMBER =    1

     BEAM-NODE       MESH-NODE      CONNECTED-GROUP-ELEMENTS
     SEQUENCE        NUMBER         FOREWARD-#     BACKWARD-#
         1             198              1              0
         2             194              2              1
         3             190              3              2
         4             167              4              3
```

5	164	5	4
6	161	6	5
7	158	7	6
8	138	8	7
9	136	9	8
10	134	10	9
11	132	11	10
12	130	12	11
13	128	13	12
14	118	14	13
15	115	15	14
16	109	16	15
17	103	17	16
18	97	18	17
19	91	19	18
20	80	0	19

```
MATERIAL DESCRIPTION FOR SOILS AND INTERFACE
(ALL DENSITY UNITS ARE pcf, ALL MODULUS UNITS ARE psi)

   PROPERTIES FOR MATERIAL  1   ********in site

        DENSITY =    0.14000E+03

        YOUNGS MODULUS= 0.5000E+04
        POISSONS RATIO= 0.3500E+00
        CONFINED MOD.= 0.8025E+04
        LATERAL COEFF.= 0.5385E+00

   PROPERTIES FOR MATERIAL  2   ********Footing

        DENSITY =    0.15000E+03

        YOUNGS MODULUS= 0.3122E+07
        POISSONS RATIO= 0.1700E+00
        CONFINED MOD.= 0.3356E+07
        LATERAL COEFF.= 0.2048E+00

   PROPERTIES FOR MATERIAL  3   ********SW95

        DENSITY =    0.14000E+03

   CONTROLS FOR DUNCAN SOIL MODEL
   WITH SELIG HYPERBOLIC BULK MODULUS FORMULATION

         LRFD STRESS CONTROL..........        0

         ENTERING ELEMENT RATIO.......      0.5000


   HYPERBOLIC STRESS-STRAIN PARAMETERS


         SOIL CLASSIFICATION ............SW95
```

COHESION INTERCEPT C 0.0000

FRICTION ANGLE PHIO (DEG)..... 48.0000

10-FOLD REDUCTION IN PHIO(DEG).. 8.0000

SCALED MODULUS NUMBER ZK 950.0000

MODULUS EXPONENT ZN 0.6000

FAILURE RATIO RF 0.7000

INIT. BULK MODULUS NUMBER BI.... 74.8000

ULT. VOLUMETRIC STRAIN EU 0.0200

INTERFACE ELEMENT MATERIAL-GROUP PROPERTIES

MAT. NO.	NORMAL-ANGLE	COEF-FRICTION	TENSILE-RUPTURE	INITIAL-GAP
1	90.00	0.40000	10.00000	0.00000
2	88.11	0.40000	10.00000	0.00000
3	86.22	0.40000	10.00000	0.00000
4	84.32	0.40000	10.00000	0.00000
5	82.43	0.40000	10.00000	0.00000
6	80.54	0.40000	10.00000	0.00000
7	78.65	0.40000	10.00000	0.00000
8	76.76	0.40000	10.00000	0.00000
9	74.87	0.40000	10.00000	0.00000
10	72.97	0.40000	10.00000	0.00000
11	71.08	0.40000	10.00000	0.00000
12	69.19	0.40000	10.00000	0.00000
13	67.30	0.40000	10.00000	0.00000
14	65.41	0.40000	10.00000	0.00000
15	10.46	0.40000	10.00000	0.00000
16	5.11	0.40000	10.00000	0.00000
17	0.00	0.40000	10.00000	0.00000
18	0.00	0.40000	10.00000	0.00000
19	0.00	0.40000	10.00000	0.00000

LRFD TOTAL LOAD FACTORS PER LOAD STEP

LOAD STEP	LOAD FACTOR	USER COMMENT
1	1.310	Factor for load step #1
2	0.857	Factor for load step #2
3	0.857	Factor for load step #3
4	0.857	Factor for load step #4
5	1.365	Factor for load step #5
6	1.365	Factor for load step #6
7	1.365	Factor for load step #7

8	1.365	Factor for load step #8
9	1.500	Factor for load step #9
10	1.750	Factor for load step #10
11	1.750	Factor for load step #11
12	1.750	Factor for load step #12
13	1.750	Factor for load step #13

+ +

SOLUTION OUTPUT RESULTS

+ +

FINITE ELEMENT OUTPUT FOR LOAD STEP 13

+ +

CONCRETE, FACTORED-EVALUATION FOR GROUP 1, LOAD-STEP 13

STRUCTURAL RESPONSES OF CONCRETE-GROUP 1, LOAD-STEP 13
COORDINATES, DISPLACEMENTS AND CRACK DEPTHS ARE INCHES
Y-BAR IS "NEUTRAL AXIS" LOCATION FROM INTERIOR, INCHES
PRESSURES ARE LB/IN**2
MOMENTS ARE IN-LB/IN
THRUST AND SHEAR ARE LB/IN

LOCAL NODE	X-COORD. Y-COORD.	X-DISP. Y-DISP.	N-PRES. S-PRES.	MOMENT THRUST	Y-BAR CRACK DEPTH
1	0.00	0.00000E+00	-0.38927E+01	0.33690E+05	0.66148E+01
	125.00	-0.24466E+01	-0.11901E+01	-0.20928E+04	0.60828E+01
2	13.42	-0.81521E-03	-0.37692E+01	0.33706E+05	0.66148E+01
	124.78	-0.24312E+01	-0.35677E+00	-0.20978E+04	0.60817E+01
3	26.80	0.39870E-03	-0.36458E+01	0.33816E+05	0.66148E+01
	124.11	-0.23852E+01	0.47658E+00	-0.20973E+04	0.60837E+01
4	40.15	0.56782E-02	-0.83928E+01	0.34044E+05	0.66148E+01
	123.01	-0.23086E+01	0.31929E+01	-0.20736E+04	0.60912E+01
5	53.46	0.17075E-01	-0.18312E+02	0.33527E+05	0.66148E+01
	121.47	-0.22016E+01	0.46269E+01	-0.20249E+04	0.60904E+01
6	66.71	0.36509E-01	-0.22746E+02	0.30465E+05	0.66148E+01
	119.48	-0.20655E+01	-0.75712E+00	-0.20088E+04	0.60427E+01

7	79.89	0.65255E-01	-0.29072E+02	0.24053E+05	0.65930E+01
	117.06	-0.19041E+01	-0.63016E+01	-0.20746E+04	0.58918E+01
8	92.98	0.10352E+00	-0.38262E+02	0.13183E+05	0.63124E+01
	114.21	-0.17250E+01	-0.15238E+02	-0.22492E+04	0.49522E+01
9	105.97	0.15009E+00	-0.18153E+02	-0.37130E+04	0.35323E+01
	110.92	-0.15373E+01	-0.62472E+01	-0.24354E+04	0.38076E+01
10	118.85	0.20133E+00	-0.30807E+02	-0.22943E+05	0.30809E+01
	107.21	-0.13553E+01	-0.12285E+02	-0.26118E+04	0.67099E+01
11	131.59	0.25181E+00	-0.87995E+01	-0.46713E+05	0.34778E+01
	103.08	-0.11954E+01	-0.34984E+01	-0.27779E+04	0.82367E+01
12	144.19	0.29784E+00	-0.92388E+01	-0.71019E+05	0.40882E+01
	98.53	-0.10645E+01	-0.36912E+01	-0.28915E+04	0.10405E+02
13	156.64	0.33874E+00	-0.93247E+01	-0.95931E+05	0.45666E+01
	93.56	-0.95897E+00	-0.37384E+01	-0.30104E+04	0.13503E+02
14	168.91	0.37595E+00	-0.10364E+02	-0.12147E+06	0.57315E+01
	88.19	-0.87137E+00	-0.10976E+02	-0.33249E+04	0.19596E+02
15	171.76	0.44998E+00	-0.10951E+02	-0.10564E+06	0.45063E+01
	75.95	-0.85298E+00	-0.31057E+01	-0.35458E+04	0.12838E+02
16	173.47	0.50560E+00	-0.15033E+02	-0.87442E+05	0.39865E+01
	63.50	-0.84404E+00	-0.29653E+01	-0.34682E+04	0.92668E+01
17	174.00	0.52723E+00	-0.16798E+02	-0.67540E+05	0.36408E+01
	50.94	-0.84167E+00	0.49572E-01	-0.33982E+04	0.80649E+01
18	174.00	0.49506E+00	-0.11654E+02	-0.42443E+05	0.35182E+01
	33.96	-0.83960E+00	0.39474E+01	-0.33484E+04	0.77347E+01
19	174.00	0.41310E+00	-0.35752E+01	-0.20706E+05	0.36437E+01
	16.98	-0.83774E+00	0.11074E+01	-0.33232E+04	0.68677E+01
20	174.00	0.31141E+00	0.45039E+01	0.58003E-09	0.61687E+01
	0.00	-0.83658E+00	-0.17326E+01	-0.33220E+04	0.00000E+00

SHEAR FORCE DIAGNOSTCS FOR CONCRETE-GROUP 1, LOAD STEP 13
-- V-factor is coefficient of sqrt(PFPC) equal to capacity.
-- Shear depth "d" is negative if measured from outer wall.
-- Stirrup load is excess shear force above capacity.

NODE	EQUIVALENT V-factor	SHEAR CAPACITY lbs/inch	APPLIED SHEAR lbs/inch	APPLIED/ CAPACITY ratio	SHEAR DEPTH-d inches	STIRRUP LOAD lbs/inch
1	2.87	1850.73	2.28	0.001	8.00	0.00
2	2.87	1851.15	-4.69	0.003	8.00	0.00
3	2.87	1851.10	-12.61	0.007	8.00	0.00
4	2.87	1849.12	10.76	0.006	8.00	0.00
5	2.86	1845.04	133.56	0.072	8.00	0.00
6	2.86	1843.69	353.55	0.192	8.00	0.00
7	2.85	1850.91	644.90	0.348	8.06	0.00
8	4.50	2923.16	1036.13	0.354	8.06	0.00

9	4.50	2764.55	1348.15	0.488	-7.63	0.00
10	4.12	2718.92	1604.65	0.590	-8.19	0.00
11	2.63	2093.26	1794.01	0.857	-9.88	0.00
12	1.99	2038.43	1836.61	0.901	-12.69	0.00
13	1.72	2310.57	1882.73	0.815	-16.69	0.00
14	1.47	2903.28	322.89	0.111	-24.56	0.00
15	1.75	2244.59	-1354.01	0.603	-15.88	0.00
16	2.14	1921.39	-1515.31	0.789	-11.13	0.00
17	2.37	1826.74	-1530.57	0.838	-9.56	0.00
18	2.42	1865.91	-1379.14	0.739	-9.56	0.00
19	3.95	3044.36	-1249.84	0.411	-9.56	0.00
20	4.50	3625.40	-1189.14	0.328	10.00	0.00

STRESS AND STRAIN MEASURES FOR CONCRETE-GROUP 1, LOAD STEP 13

NODE	MAXIMUM COMPRESSION psi	AVERAGE SHEAR psi	RADIAL TENSION psi	INNER-WALL STRAIN in/in	OUTER-WALL STRAIN in/in
1	-3118.26	0.29	10.97	0.1049E-02	-0.6589E-03
2	-3120.60	-0.60	10.97	0.1049E-02	-0.6594E-03
3	-3128.17	-1.62	11.05	0.1052E-02	-0.6610E-03
4	-3143.08	1.38	11.12	0.1061E-02	-0.6642E-03
5	-3086.96	17.16	10.94	0.1042E-02	-0.6523E-03
6	-2825.82	45.44	9.79	0.9371E-03	-0.5971E-03
7	-2238.10	82.21	7.15	0.6922E-03	-0.4729E-03
8	-1271.72	132.09	2.66	0.2801E-03	-0.2687E-03
9	-1271.72	171.87	0.00	-0.1539E-03	0.9369E-04
10	-2388.60	190.89	0.00	-0.5047E-03	0.8922E-03
11	-3277.03	177.73	0.00	-0.6977E-03	0.1440E-02
12	-3265.49	142.30	0.00	-0.6930E-03	0.1560E-02
13	-2852.88	111.36	0.00	-0.6029E-03	0.1482E-02
14	-2030.07	13.03	0.00	-0.4290E-03	0.1172E-02
15	-3343.00	-84.13	0.00	-0.7244E-03	0.1732E-02
16	-4205.30	-133.58	0.00	-0.1073E-02	0.2345E-02
17	-4214.41	-156.48	0.00	-0.1076E-02	0.2237E-02
18	-3344.67	-141.00	0.00	-0.7250E-03	0.1343E-02
19	-1884.12	-127.78	0.00	-0.3981E-03	0.5562E-03
20	-248.90	-121.57	0.00	-0.5260E-04	-0.5260E-04

STEEL STRESS AND CRACK WIDTHS FOR CONCRETE-GROUP 1, LOAD STEP 13
NOTE: CRACK WIDTH IS REDUCED TO SERVICE-LOAD LEVEL.
ALL OTHER RESPONSES ARE AT FACTORED LOAD LEVEL.

NODE	INNER CAGE psi	OUTER CAGE psi	MAX STRESS TO YIELD ratio	CRACK WIDTH inches
1	22537.68	-7733.99	0.3756	0.00243
2	22541.94	-7743.65	0.3757	0.00241
3	22617.04	-7756.26	0.3770	0.00238
4	22806.68	-7768.28	0.3801	0.00237
5	22402.04	-7628.77	0.3734	0.00214
6	20084.68	-7112.06	0.3347	0.00130
7	14678.25	-6078.26	0.2446	0.00000
8	5449.64	-4327.63	0.0908	0.00000
9	-3336.90	1074.36	0.0556	0.00000
10	-7705.52	18219.84	0.3037	0.00000

11	-11168.96	32403.66	0.5401	0.00236
12	-12593.06	38133.61	0.6356	0.00278
13	-12264.29	38757.99	0.6460	0.00078
14	-9892.23	32736.96	0.5456	0.00000
15	-14535.32	44772.69	0.7462	0.00336
16	-18124.13	55169.33	0.9195	0.00962
17	-16707.44	49832.86	0.8305	0.00861
18	-12121.92	29409.26	0.4902	0.00149
19	-7619.52	11546.27	0.1924	0.00000
20	-1676.16	-1676.16	0.0279	0.00000

ASSESSMENT SUMMARY CONCRETE-GROUP 1, LOAD-STEP 13

LRFD SUMMARY EVALUATION FOR GROUP 1, LOAD STEP 13

DESIGN-CRITERION	CONTROL NODE	FACTORED DEMAND	FACTORED CAPACITY	RATIO VALUE
STEEL YIELDING (psi)	16	55169.3	60000.0	0.919
CONCRETE CRUSHING (psi)	17	4214.4	4875.0	0.864
SHEAR FAILURE (lbs/in)	12	1836.6	1834.6	1.001
RADIAL-TENSION FAIL (psi)	4	11.1	69.6	0.160

LRFD SERVICE-LOAD PERFORMANCE MEASURES FOR GROUP 1, LOAD STEP 13

NODE NUMBER FOR MAXIMUM CRACK WIDTH 16

MAXIMUM CRACK WIDTH AT SERVICE LOAD (inches) 0.00962

LRFD RATIO: MAX-CRACK-WIDTH / ALLOWABLE 0.96

SPAN LENGTH FOR AUXILIARY EQUATIONS (inches)..... 348.00

* * * * NORMAL EXIT FROM CANDE * * * *

28x10H20c1Mod.out

```
*** WELCOME TO CANDE-2013(version 3/1/2013) ***

MASTER CONTROL AND PIPE-TYPE DATA FOR PROBLEM #  1

        USER TITLE: 28x10

        EXECUTION MODE ..................   ANALYS

        SOLUTION LEVEL ..................  #2 AUTO

        METHODOLOGY (LRFD OR SERVICE) ...     LRFD

        NUMBER OF PIPE-ELEMENT GROUPS ....       1

        MAXIMUM ITERATIONS PER STEP ......      30


        CULVERT PIPE-TYPE ............... CONCRETE

        CANNED MESH CODE # ..............        3

        NUMBER OF BEAM ELEMENTS .........       19

        CONCRETE MATERIAL PROPERTIES ARE AS FOLLOWS

             COMPRESSION STRENGTH (psi)..........       6500.000

             ELASTIC YOUNGS MODULUS (psi)........    4595487.000

             POISSON RATIO ......................          0.170

             CONCRETE DENSITY (pcf) .............        150.000

             INITIAL TENSILE CRACKING STRAIN.....       0.000010

             INITIAL COMPRESSION YIELD STRAIN....       0.000687

             INITIAL COMPRESSION CRUSH STRAIN ...       0.002000

             SHEAR STRENGTH MODEL (NSHEAR) # ...          1
             (VARIABLE STRENGTH MODEL PRINTED IN OUTPUT)

             CONCRETE CRACK-WIDTH MODEL NAME.....   HEGER-McGRATH
             (DRIVEN BY TENSILE STRAIN IN STEEL)

        STEEL REINFORCEMENT MATERIAL PROPERTIES

             TYPE OF STEEL CAGES (RSHAPE) .......     ARBIT

             STEEL YIELD STRENGTH (psi)..........      60000.000

             STEEL ELASTIC MODULUS (psi).........   29000000.000
```

STEEL POISSON RATIO 0.300000

STEEL YIELDING STRAIN 0.001883

NONLINEAR MODELING CODE (1,2,3) 3

STEEL-BASED CRACKWIDTH PREDICTION PARAMETERS
REBAR SPACING INNER ROW (SLI), (in) 4.00
REBAR SPACING OUTER ROW (SLO), (in) 4.00
NUMBER OF STEEL LAYERS FOR INNER CAGE 1
NUMBER OF STEEL LAYERS FOR OUTER CAGE 1
HEGER-MCGRATH CODE NUMBER FOR STEEL TYPE.. 3

WALL THICKNESS, REBAR AREAS AND COVER DEPTHS

WALL-THICK	INNER-REBAR	OUTER-REBAR	INNER-COVER	OUTER COVER
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1100	0.1500	2.0000	2.4375
10.6250	0.1100	0.1500	2.0000	2.4375
12.3130	0.1100	0.1500	2.0000	2.4375
15.1250	0.1100	0.1500	2.0000	2.4375
19.1250	0.1100	0.1500	2.0000	2.4375
27.0000	0.1100	0.1500	2.0000	2.4375
18.3130	0.1100	0.1500	2.0000	2.4375
13.5630	0.1100	0.1500	2.0000	2.4375
12.0000	0.1100	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375

LRFD RESISTANCE FACTORS FOR STRENGTH-LIMIT STATES
AND CRACK-WIDTH LIMIT AT SERVICE LOAD

YIELDING OF REINFORCEMENT STEEL 1.000

CRUSHING OF CONCRETE OUTER FIBER..... 0.750

SHEARING FAILURE OF CONCRETE 0.900

SPLITTING OF CONCRETE IN RADIAL TENSION 0.900

ALLOWABLE CRACKWIDTH SERVICE LOAD (inch).... 0.010

LARGE DEFORMATION/BUCKLING CODE, IBUCK = 0
IBUCK=0, MEANS SMALL DEFORMATION THEORY FOR GROUP
AND NO BUCKLING PREDICTION.

28x10H2Oc1Mod.out

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


 REVIEW SYSTEM INPUT DATA


 LEVEL-2 DATA FOR ARCH-TYPE CANNED MESH


    *** MESH PARAMETERS ***
     TYPE OF MESH ------------------------------------- TREN
     DEPTH OF TRENCH ABOVE FOOTING LEVEL (FT) ---------   12.42
     WIDTH OF TRENCH AT FOOTING LEVEL (FT) ------------    5.00
     SLOPE OF TRENCH WALL (H/V) -----------------------    0.00
     MESH SPACING PARAMETER ---------------------------    1.00
     TOTAL SOIL HEIGHT ABOVE CROWN (FT) ---------------    2.00
     MESH HEIGHT ABOVE CROWN (FT) ----------------------    2.00
     SOIL DENSITY ABOVE MESH (PCF) --------------------  140.00
     NUMBER OF ELEMENT LAYERS ABOVE CROWN -------------    3


*** ARCH PARAMETERS ***
     CENTERLINE RISE OF ARCH (IN) ----------------------  125.00
     BOTTOM HALF SPAN OF ARCH (IN) ---------------------  174.00
     SIDE RISE OF ARCH ABOVE FOOTING (IN) -------------   50.94
     FOOTING DEPTH (IN) --------------------------------   24.00
     OUTSIDE FOOTING WIDTH (IN) ------------------------   30.00
     INSIDE FOOTING WIDTH (IN) -------------------------   30.00
     NUMBER OF ARCH SEGMENTS DEFINED -------------------    3

*** CURVED TOP SEGMENT ***
     RADIUS (IN) ---------------------------------------  405.88
     CENTRAL ANGLE (DEG) -------------------------------   24.59
     SEGMENT ARC LENGTH (IN) ---------------------------  174.19
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------   13

*** CURVED CORNER SEGMENT ***
     RADIUS (IN) ---------------------------------------  133.94
     CENTRAL ANGLE (DEG) -------------------------------   16.14
     SEGMENT ARC LENGTH (IN) ---------------------------   37.73
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

*** STRAIGHT SIDE SEGMENT ***
     DEFLECTION ANGLE (DEG) ----------------------------   90.00
     SEGMENT LENGTH (IN) -------------------------------   50.94
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

 FINITE ELEMENT INPUT CONTROLS (PREP)


THE DATA TO BE RUN IS ENTITLED ...

New Level 2 arch mesh

PRINT AND PLOT CONTROL CODES ...
  PRINT CONTROL FOR MESH DATA------------    1
  PLOT FILE CONTROL MESH & RESULS--------    3
  PRINT FINITE ELEMENT RESULTS ----------    1
  INPUT DATA CHECK CODE------------------    0
```

28x10H20c1Mod.out

```
KEY NUMBERS DESCRIBING MESH ...
  THE NUMBER OF LOAD STEPS IS------------   13
  TOTAL NUMBER OF NODES IS---------------  244
  TOTAL NUMBER OF ELEMENTS IS------------  209
  TOTAL NUMBER OF BEAM ELEMENTS IS-------   19
  MAX NUMBER OF BOUNDARY CONDITIONS IS---   36


 EXTENDED LEVEL-2: CHANGES TO CANNED MESH

          * NUMBER OF NODES TO BE CHANGED -------      0 *
          * NUMBER OF ELEMENTS TO BE CHANGED ----      0 *
          * ADDITIONAL BOUNDARY CONDITIONS ------     31 *


 * * * BOUNDARY CONDITIONS * * *
  (FORCES = LBS; DISPLACEMENTS = INCHES; ROTATIONS = DEGREES)

  BOUNDARY      LOAD      X-FORCE     OR      Y-FORCE     OR      X-Y ROTATION
BEAM ROTATIONAL
     NODE       STEP      X-DISPLACEMENT      Y-DISPLACEMENT
BOUNDARY CONDITIONS

      224        10    F =   0.0000E+00    F =  -0.8925E+02      0.0000E+00
     F
      224        11    F =   0.0000E+00    F =  -0.8925E+02      0.0000E+00
     F
      224        12    F =   0.0000E+00    F =  -0.8925E+02      0.0000E+00
     F
      224        13    F =   0.0000E+00    F =  -0.8925E+02      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        11    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        12    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        13    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      224        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      225        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      226        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      227        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      228        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
```

28x10H20c1Mod.out

```
F
 231        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 232        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 233        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 224         9    F =   0.0000E+00    F =  -0.2188E+01      0.0000E+00
F
 225         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 226         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 227         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 228         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 229         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 230         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 231         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 232         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 233         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 234         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 235         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 236         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F

* * * * * COMPLETED MESH GENERATION  * * * * *

New Level 2 arch mesh

CALCULATED KEY NUMBERS ...
  THE NUMBER OF DATA ERRORS IS-----------    0
  THE NUMBER OF SOIL MATERIALS IS--------    3
  THE NUMBER OF PIPE-TYPE GROUPS IS------    1
  THE NUMBER OF INTERFACE MATERIALS IS---   19
  BAND WIDTH ESTIMATE (MAX)--------------   88


* * * * MESH DATA HAS BEEN SAVED ON UNIT 14 * * * *


 BEAM-NODE SEQUENCE NUMBERS FOR EACH GROUP


    BEAM-ELEMENT GROUP NUMBER =    1

     BEAM-NODE       MESH-NODE      CONNECTED-GROUP-ELEMENTS
     SEQUENCE        NUMBER         FOREWARD-#    BACKWARD-#
         1             198              1              0
         2             194              2              1
         3             190              3              2
         4             167              4              3
```

5	164	5	4
6	161	6	5
7	158	7	6
8	138	8	7
9	136	9	8
10	134	10	9
11	132	11	10
12	130	12	11
13	128	13	12
14	118	14	13
15	115	15	14
16	109	16	15
17	103	17	16
18	97	18	17
19	91	19	18
20	80	0	19

```
MATERIAL DESCRIPTION FOR SOILS AND INTERFACE
(ALL DENSITY UNITS ARE pcf, ALL MODULUS UNITS ARE psi)

   PROPERTIES FOR MATERIAL  1   ********in site

        DENSITY =    0.14000E+03

        YOUNGS MODULUS= 0.5000E+04
        POISSONS RATIO= 0.3500E+00
        CONFINED MOD.= 0.8025E+04
        LATERAL COEFF.= 0.5385E+00

   PROPERTIES FOR MATERIAL  2   ********Footing

        DENSITY =    0.15000E+03

        YOUNGS MODULUS= 0.3122E+07
        POISSONS RATIO= 0.1700E+00
        CONFINED MOD.= 0.3356E+07
        LATERAL COEFF.= 0.2048E+00

   PROPERTIES FOR MATERIAL  3   ********SW95

        DENSITY =    0.14000E+03

   CONTROLS FOR DUNCAN SOIL MODEL
   WITH SELIG HYPERBOLIC BULK MODULUS FORMULATION

         LRFD STRESS CONTROL..........       0

         ENTERING ELEMENT RATIO.......      0.5000


   HYPERBOLIC STRESS-STRAIN PARAMETERS


         SOIL CLASSIFICATION ............SW95
```

COHESION INTERCEPT C 0.0000

FRICTION ANGLE PHIO (DEG)..... 48.0000

10-FOLD REDUCTION IN PHIO(DEG).. 8.0000

SCALED MODULUS NUMBER ZK 950.0000

MODULUS EXPONENT ZN 0.6000

FAILURE RATIO RF 0.7000

INIT. BULK MODULUS NUMBER BI.... 74.8000

ULT. VOLUMETRIC STRAIN EU 0.0200

INTERFACE ELEMENT MATERIAL-GROUP PROPERTIES

MAT. NO.	NORMAL-ANGLE	COEF-FRICTION	TENSILE-RUPTURE	INITIAL-GAP
1	90.00	0.40000	10.00000	0.00000
2	88.11	0.40000	10.00000	0.00000
3	86.22	0.40000	10.00000	0.00000
4	84.32	0.40000	10.00000	0.00000
5	82.43	0.40000	10.00000	0.00000
6	80.54	0.40000	10.00000	0.00000
7	78.65	0.40000	10.00000	0.00000
8	76.76	0.40000	10.00000	0.00000
9	74.87	0.40000	10.00000	0.00000
10	72.97	0.40000	10.00000	0.00000
11	71.08	0.40000	10.00000	0.00000
12	69.19	0.40000	10.00000	0.00000
13	67.30	0.40000	10.00000	0.00000
14	65.41	0.40000	10.00000	0.00000
15	10.46	0.40000	10.00000	0.00000
16	5.11	0.40000	10.00000	0.00000
17	0.00	0.40000	10.00000	0.00000
18	0.00	0.40000	10.00000	0.00000
19	0.00	0.40000	10.00000	0.00000

LRFD TOTAL LOAD FACTORS PER LOAD STEP

LOAD STEP	LOAD FACTOR	USER COMMENT
1	1.310	Factor for load step #1
2	0.857	Factor for load step #2
3	0.857	Factor for load step #3
4	0.857	Factor for load step #4
5	1.365	Factor for load step #5
6	1.365	Factor for load step #6
7	1.365	Factor for load step #7

8	1.365	Factor for load step #8
9	1.500	Factor for load step #9
10	1.750	Factor for load step #10
11	1.750	Factor for load step #11
12	1.750	Factor for load step #12
13	1.750	Factor for load step #13

+ +

SOLUTION OUTPUT RESULTS

+ +

FINITE ELEMENT OUTPUT FOR LOAD STEP 13

+ +

CONCRETE, FACTORED-EVALUATION FOR GROUP 1, LOAD-STEP 13

STRUCTURAL RESPONSES OF CONCRETE-GROUP 1, LOAD-STEP 13
COORDINATES, DISPLACEMENTS AND CRACK DEPTHS ARE INCHES
Y-BAR IS "NEUTRAL AXIS" LOCATION FROM INTERIOR, INCHES
PRESSURES ARE LB/IN**2
MOMENTS ARE IN-LB/IN
THRUST AND SHEAR ARE LB/IN

LOCAL NODE	X-COORD. Y-COORD.	X-DISP. Y-DISP.	N-PRES. S-PRES.	MOMENT THRUST	Y-BAR CRACK DEPTH
1	0.00	0.00000E+00	-0.40977E+02	0.49334E+05	0.65127E+01
	125.00	-0.18733E+01	-0.16276E+02	-0.98635E+03	0.64011E+01
2	13.42	-0.16499E-03	-0.25417E+02	0.45585E+05	0.65207E+01
	124.78	-0.18511E+01	-0.10066E+02	-0.11361E+04	0.63656E+01
3	26.80	0.23631E-02	-0.98562E+01	0.37621E+05	0.66090E+01
	124.11	-0.17879E+01	-0.38552E+01	-0.12479E+04	0.63099E+01
4	40.15	0.97569E-02	-0.15130E+01	0.28284E+05	0.66148E+01
	123.01	-0.16909E+01	-0.52680E+00	-0.13003E+04	0.61945E+01
5	53.46	0.23321E-01	-0.35307E+00	0.19096E+05	0.65476E+01
	121.47	-0.15686E+01	-0.70360E-01	-0.13282E+04	0.59601E+01
6	66.71	0.43493E-01	-0.37970E+01	0.10278E+05	0.65476E+01
	119.48	-0.14298E+01	-0.14562E+01	-0.13622E+04	0.54296E+01

7	79.89	0.69859E-01	-0.28373E+01	0.12264E+04	0.52563E+01
	117.06	-0.12834E+01	-0.10823E+01	-0.14035E+04	0.12332E+00
8	92.98	0.10117E+00	-0.36545E+01	-0.78687E+04	0.24151E+01
	114.21	-0.11377E+01	-0.14186E+01	-0.14452E+04	0.65580E+01
9	105.97	0.13502E+00	-0.44582E+01	-0.17132E+05	0.29481E+01
	110.92	-0.10015E+01	-0.17490E+01	-0.14923E+04	0.65187E+01
10	118.85	0.16784E+00	-0.54049E+01	-0.26689E+05	0.30809E+01
	107.21	-0.88494E+00	-0.21359E+01	-0.15454E+04	0.70931E+01
11	131.59	0.19672E+00	-0.62439E+01	-0.36695E+05	0.34674E+01
	103.08	-0.79344E+00	-0.24797E+01	-0.16053E+04	0.83678E+01
12	144.19	0.22079E+00	-0.71169E+01	-0.47298E+05	0.40809E+01
	98.53	-0.72476E+00	-0.28397E+01	-0.16727E+04	0.10447E+02
13	156.64	0.24078E+00	-0.86976E+01	-0.58664E+05	0.45666E+01
	93.56	-0.67298E+00	-0.34894E+01	-0.17510E+04	0.13483E+02
14	168.91	0.25810E+00	-0.10579E+02	-0.71105E+05	0.57315E+01
	88.19	-0.63205E+00	-0.72816E+01	-0.18916E+04	0.19484E+02
15	171.76	0.29120E+00	-0.82593E+01	-0.61090E+05	0.47460E+01
	75.95	-0.62376E+00	-0.23868E+01	-0.19763E+04	0.12790E+02
16	173.47	0.31357E+00	-0.10027E+02	-0.50116E+05	0.37441E+01
	63.50	-0.61999E+00	-0.26232E+01	-0.19449E+04	0.93097E+01
17	174.00	0.31668E+00	-0.11093E+02	-0.38448E+05	0.33970E+01
	50.94	-0.61905E+00	-0.19731E+00	-0.19173E+04	0.81019E+01
18	174.00	0.28645E+00	-0.68518E+01	-0.24102E+05	0.34814E+01
	33.96	-0.61790E+00	0.22776E+01	-0.18972E+04	0.76986E+01
19	174.00	0.22833E+00	-0.22144E+01	-0.11732E+05	0.36437E+01
	16.98	-0.61689E+00	0.56279E+00	-0.18908E+04	0.67237E+01
20	174.00	0.15919E+00	0.24230E+01	0.17258E-09	0.61687E+01
	0.00	-0.61624E+00	-0.11520E+01	-0.18989E+04	0.00000E+00

SHEAR FORCE DIAGNOSTCS FOR CONCRETE-GROUP 1, LOAD STEP 13
-- V-factor is coefficient of sqrt(PFPC) equal to capacity.
-- Shear depth "d" is negative if measured from outer wall.
-- Stirrup load is excess shear force above capacity.

NODE	EQUIVALENT V-factor	SHEAR CAPACITY lbs/inch	APPLIED SHEAR lbs/inch	APPLIED/ CAPACITY ratio	SHEAR DEPTH-d inches	STIRRUP LOAD lbs/inch
1	2.73	1758.04	121.84	0.069	8.00	0.00
2	2.75	1770.59	436.88	0.247	8.00	0.00
3	2.76	1779.95	645.62	0.363	8.00	0.00
4	2.77	1784.34	691.30	0.387	8.00	0.00
5	2.77	1786.68	671.95	0.376	8.00	0.00
6	4.15	2679.72	666.83	0.249	8.00	0.00
7	4.50	2923.16	677.16	0.232	8.06	0.00
8	3.51	2155.83	685.07	0.318	-7.63	0.00

9	2.69	1651.84	702.32	0.425	-7.63	0.00
10	2.46	1626.00	730.05	0.449	-8.19	0.00
11	2.17	1725.96	769.06	0.446	-9.88	0.00
12	1.87	1912.67	819.79	0.429	-12.69	0.00
13	1.64	2204.53	888.41	0.403	-16.69	0.00
14	1.43	2830.69	65.56	0.023	-24.56	0.00
15	1.69	2156.90	-835.14	0.387	-15.88	0.00
16	2.04	1825.72	-900.51	0.493	-11.13	0.00
17	2.24	1728.00	-886.52	0.513	-9.56	0.00
18	2.30	1772.54	-786.72	0.444	-9.56	0.00
19	3.75	2890.28	-709.75	0.246	-9.56	0.00
20	4.50	3625.40	-672.15	0.185	10.00	0.00

STRESS AND STRAIN MEASURES FOR CONCRETE-GROUP 1, LOAD STEP 13

NODE	MAXIMUM COMPRESSION psi	AVERAGE SHEAR psi	RADIAL TENSION psi	INNER-WALL STRAIN in/in	OUTER-WALL STRAIN in/in
1	-3777.28	15.66	17.41	0.1628E-02	-0.8998E-03
2	-3621.03	56.15	15.93	0.1493E-02	-0.8367E-03
3	-3267.42	82.97	12.95	0.1213E-02	-0.6938E-03
4	-2532.72	88.84	9.49	0.8975E-03	-0.5352E-03
5	-1788.77	86.35	6.08	0.5824E-03	-0.3780E-03
6	-1062.21	85.70	2.89	0.2885E-03	-0.2245E-03
7	-254.14	86.33	0.00	0.6663E-06	-0.5370E-04
8	-959.64	87.33	0.00	-0.2028E-03	0.4081E-03
9	-1884.89	89.53	0.00	-0.3983E-03	0.7610E-03
10	-2508.92	86.85	0.00	-0.5302E-03	0.1095E-02
11	-2497.16	76.19	0.00	-0.5277E-03	0.1150E-02
12	-2147.63	63.52	0.00	-0.4538E-03	0.1046E-02
13	-1728.94	52.55	0.00	-0.3654E-03	0.9070E-03
14	-1177.28	2.65	0.00	-0.2488E-03	0.6809E-03
15	-1970.86	-51.89	0.00	-0.4165E-03	0.9977E-03
16	-2804.07	-79.38	0.00	-0.5925E-03	0.1329E-02
17	-2789.61	-90.63	0.00	-0.5895E-03	0.1256E-02
18	-1938.18	-80.43	0.00	-0.4096E-03	0.7609E-03
19	-1050.58	-72.56	0.00	-0.2220E-03	0.3056E-03
20	-142.27	-68.72	0.00	-0.3006E-04	-0.3006E-04

STEEL STRESS AND CRACK WIDTHS FOR CONCRETE-GROUP 1, LOAD STEP 13
NOTE: CRACK WIDTH IS REDUCED TO SERVICE-LOAD LEVEL.
ALL OTHER RESPONSES ARE AT FACTORED LOAD LEVEL.

NODE	INNER CAGE psi	OUTER CAGE psi	MAX STRESS TO YIELD ratio	CRACK WIDTH inches
1	35775.92	-9038.34	0.5963	0.00643
2	32730.85	-8567.18	0.5455	0.00549
3	26514.95	-7295.00	0.4419	0.00356
4	19469.69	-5927.04	0.3245	0.00136
5	12439.06	-4585.72	0.2073	0.00000
6	5925.46	-3168.30	0.0988	0.00000
7	-323.13	-1291.73	0.0215	0.00000
8	-2593.05	8290.67	0.1382	0.00000
9	-5350.72	15302.10	0.2550	0.00000
10	-7147.79	23009.82	0.3835	0.00000

11	-8129.79	26076.25	0.4346	0.00031
12	-8142.92	25628.30	0.4271	0.00000
13	-7402.75	23737.30	0.3956	0.00000
14	-5733.50	19024.25	0.3171	0.00000
15	-8350.42	25796.24	0.4299	0.00000
16	-9854.15	31343.50	0.5224	0.00192
17	-8984.02	28079.46	0.4680	0.00158
18	-6835.20	16672.89	0.2779	0.00000
19	-4272.34	6324.74	0.1054	0.00000
20	-958.11	-958.11	0.0160	0.00000

ASSESSMENT SUMMARY CONCRETE-GROUP 1, LOAD-STEP 13

LRFD SUMMARY EVALUATION FOR GROUP 1, LOAD STEP 13

DESIGN-CRITERION	CONTROL NODE	FACTORED DEMAND	FACTORED CAPACITY	RATIO VALUE
STEEL YIELDING (psi)	1	35775.9	60000.0	0.596
CONCRETE CRUSHING (psi)	1	3777.3	4875.0	0.775
SHEAR FAILURE (lbs/in)	17	886.5	1555.2	0.570
RADIAL-TENSION FAIL (psi)	1	17.4	69.6	0.250

LRFD SERVICE-LOAD PERFORMANCE MEASURES FOR GROUP 1, LOAD STEP 13

NODE NUMBER FOR MAXIMUM CRACK WIDTH 1

MAXIMUM CRACK WIDTH AT SERVICE LOAD (inches) 0.00643

LRFD RATIO: MAX-CRACK-WIDTH / ALLOWABLE 0.64

SPAN LENGTH FOR AUXILIARY EQUATIONS (inches)..... 348.00

* * * * NORMAL EXIT FROM CANDE * * * *

28x10H20c2Mod.out

```
*** WELCOME TO CANDE-2013(version 3/1/2013) ***

MASTER CONTROL AND PIPE-TYPE DATA FOR PROBLEM #  1

        USER TITLE: 28x10

        EXECUTION MODE ..................   ANALYS

        SOLUTION LEVEL ..................  #2 AUTO

        METHODOLOGY (LRFD OR SERVICE) ...     LRFD

        NUMBER OF PIPE-ELEMENT GROUPS ....       1

        MAXIMUM ITERATIONS PER STEP ......      30


        CULVERT PIPE-TYPE ............... CONCRETE

        CANNED MESH CODE # ..............        3

        NUMBER OF BEAM ELEMENTS .........       19

        CONCRETE MATERIAL PROPERTIES ARE AS FOLLOWS

             COMPRESSION STRENGTH (psi)..........       6500.000

             ELASTIC YOUNGS MODULUS (psi)........    4595487.000

             POISSON RATIO ......................          0.170

             CONCRETE DENSITY (pcf) .............        150.000

             INITIAL TENSILE CRACKING STRAIN.....       0.000010

             INITIAL COMPRESSION YIELD STRAIN....       0.000687

             INITIAL COMPRESSION CRUSH STRAIN ...       0.002000

             SHEAR STRENGTH MODEL (NSHEAR) # ...          1
             (VARIABLE STRENGTH MODEL PRINTED IN OUTPUT)

             CONCRETE CRACK-WIDTH MODEL NAME.....   HEGER-McGRATH
             (DRIVEN BY TENSILE STRAIN IN STEEL)

        STEEL REINFORCEMENT MATERIAL PROPERTIES

             TYPE OF STEEL CAGES (RSHAPE) .......     ARBIT

             STEEL YIELD STRENGTH (psi)..........      60000.000

             STEEL ELASTIC MODULUS (psi).........   29000000.000
```

28x10H20c2Mod.out

STEEL POISSON RATIO 0.300000

STEEL YIELDING STRAIN 0.001883

NONLINEAR MODELING CODE (1,2,3) 3

STEEL-BASED CRACKWIDTH PREDICTION PARAMETERS
REBAR SPACING INNER ROW (SLI), (in) 4.00
REBAR SPACING OUTER ROW (SLO), (in) 4.00
NUMBER OF STEEL LAYERS FOR INNER CAGE 1
NUMBER OF STEEL LAYERS FOR OUTER CAGE 1
HEGER-MCGRATH CODE NUMBER FOR STEEL TYPE.. 3

WALL THICKNESS, REBAR AREAS AND COVER DEPTHS

WALL-THICK	INNER-REBAR	OUTER-REBAR	INNER-COVER	OUTER COVER
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1100	0.1500	2.0000	2.4375
10.6250	0.1100	0.1500	2.0000	2.4375
12.3130	0.1100	0.1500	2.0000	2.4375
15.1250	0.1100	0.1500	2.0000	2.4375
19.1250	0.1100	0.1500	2.0000	2.4375
27.0000	0.1100	0.1500	2.0000	2.4375
18.3130	0.1100	0.1500	2.0000	2.4375
13.5630	0.1100	0.1500	2.0000	2.4375
12.0000	0.1100	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375

LRFD RESISTANCE FACTORS FOR STRENGTH-LIMIT STATES
AND CRACK-WIDTH LIMIT AT SERVICE LOAD

YIELDING OF REINFORCEMENT STEEL 1.000

CRUSHING OF CONCRETE OUTER FIBER..... 0.750

SHEARING FAILURE OF CONCRETE 0.900

SPLITTING OF CONCRETE IN RADIAL TENSION 0.900

ALLOWABLE CRACKWIDTH SERVICE LOAD (inch).... 0.010

LARGE DEFORMATION/BUCKLING CODE, IBUCK = 0
IBUCK=0, MEANS SMALL DEFORMATION THEORY FOR GROUP
AND NO BUCKLING PREDICTION.

28x10H2Oc2Mod.out

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


 REVIEW SYSTEM INPUT DATA


 LEVEL-2 DATA FOR ARCH-TYPE CANNED MESH


    *** MESH PARAMETERS ***
     TYPE OF MESH ------------------------------------- TREN
     DEPTH OF TRENCH ABOVE FOOTING LEVEL (FT) ---------   12.42
     WIDTH OF TRENCH AT FOOTING LEVEL (FT) ------------    5.00
     SLOPE OF TRENCH WALL (H/V) -----------------------    0.00
     MESH SPACING PARAMETER ---------------------------    1.00
     TOTAL SOIL HEIGHT ABOVE CROWN (FT) ---------------    2.00
     MESH HEIGHT ABOVE CROWN (FT) ----------------------    2.00
     SOIL DENSITY ABOVE MESH (PCF) --------------------  140.00
     NUMBER OF ELEMENT LAYERS ABOVE CROWN -------------    3


*** ARCH PARAMETERS ***
     CENTERLINE RISE OF ARCH (IN) ----------------------  125.00
     BOTTOM HALF SPAN OF ARCH (IN) ---------------------  174.00
     SIDE RISE OF ARCH ABOVE FOOTING (IN) -------------   50.94
     FOOTING DEPTH (IN) --------------------------------   24.00
     OUTSIDE FOOTING WIDTH (IN) ------------------------   30.00
     INSIDE FOOTING WIDTH (IN) -------------------------   30.00
     NUMBER OF ARCH SEGMENTS DEFINED -------------------    3

*** CURVED TOP SEGMENT ***
     RADIUS (IN) ---------------------------------------  405.88
     CENTRAL ANGLE (DEG) -------------------------------   24.59
     SEGMENT ARC LENGTH (IN) ---------------------------  174.19
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------   13

*** CURVED CORNER SEGMENT ***
     RADIUS (IN) ---------------------------------------  133.94
     CENTRAL ANGLE (DEG) -------------------------------   16.14
     SEGMENT ARC LENGTH (IN) ---------------------------   37.73
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

*** STRAIGHT SIDE SEGMENT ***
     DEFLECTION ANGLE (DEG) ----------------------------   90.00
     SEGMENT LENGTH (IN) -------------------------------   50.94
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

 FINITE ELEMENT INPUT CONTROLS (PREP)


THE DATA TO BE RUN IS ENTITLED ...

New Level 2 arch mesh

PRINT AND PLOT CONTROL CODES ...
  PRINT CONTROL FOR MESH DATA------------    1
  PLOT FILE CONTROL MESH & RESULS--------    3
  PRINT FINITE ELEMENT RESULTS ----------    1
  INPUT DATA CHECK CODE------------------    0
```

28x10H2Oc2Mod.out

```
 KEY NUMBERS DESCRIBING MESH ...
   THE NUMBER OF LOAD STEPS IS------------   13
   TOTAL NUMBER OF NODES IS---------------  244
   TOTAL NUMBER OF ELEMENTS IS------------  209
   TOTAL NUMBER OF BEAM ELEMENTS IS-------   19
   MAX NUMBER OF BOUNDARY CONDITIONS IS---   36



  EXTENDED LEVEL-2: CHANGES TO CANNED MESH

           * NUMBER OF NODES TO BE CHANGED -------      0 *
           * NUMBER OF ELEMENTS TO BE CHANGED ----      0 *
           * ADDITIONAL BOUNDARY CONDITIONS ------     31 *



 * * * BOUNDARY CONDITIONS * * *
  (FORCES = LBS; DISPLACEMENTS = INCHES; ROTATIONS = DEGREES)

  BOUNDARY      LOAD      X-FORCE     OR      Y-FORCE     OR      X-Y ROTATION
BEAM ROTATIONAL
     NODE       STEP      X-DISPLACEMENT      Y-DISPLACEMENT
BOUNDARY CONDITIONS

      229        10    F =   0.0000E+00    F =  -0.1785E+03      0.0000E+00
     F
      229        11    F =   0.0000E+00    F =  -0.1785E+03      0.0000E+00
     F
      229        12    F =   0.0000E+00    F =  -0.1785E+03      0.0000E+00
     F
      229        13    F =   0.0000E+00    F =  -0.1785E+03      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        11    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        12    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        13    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      224        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      225        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      226        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      227        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      228        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
```

```
F
 231        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 232        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 233        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 224         9    F =   0.0000E+00    F =  -0.2188E+01      0.0000E+00
F
 225         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 226         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 227         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 228         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 229         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 230         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 231         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 232         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 233         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 234         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 235         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 236         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F

* * * * * COMPLETED MESH GENERATION  * * * * *

New Level 2 arch mesh

CALCULATED KEY NUMBERS ...
  THE NUMBER OF DATA ERRORS IS-----------    0
  THE NUMBER OF SOIL MATERIALS IS--------    3
  THE NUMBER OF PIPE-TYPE GROUPS IS------    1
  THE NUMBER OF INTERFACE MATERIALS IS---   19
  BAND WIDTH ESTIMATE (MAX)--------------   88


* * * * MESH DATA HAS BEEN SAVED ON UNIT 14 * * * *


 BEAM-NODE SEQUENCE NUMBERS FOR EACH GROUP


    BEAM-ELEMENT GROUP NUMBER =    1

     BEAM-NODE       MESH-NODE      CONNECTED-GROUP-ELEMENTS
     SEQUENCE        NUMBER         FOREWARD-#     BACKWARD-#
         1             198              1              0
         2             194              2              1
         3             190              3              2
         4             167              4              3
```

5	164	5	4
6	161	6	5
7	158	7	6
8	138	8	7
9	136	9	8
10	134	10	9
11	132	11	10
12	130	12	11
13	128	13	12
14	118	14	13
15	115	15	14
16	109	16	15
17	103	17	16
18	97	18	17
19	91	19	18
20	80	0	19

```
MATERIAL DESCRIPTION FOR SOILS AND INTERFACE
(ALL DENSITY UNITS ARE pcf, ALL MODULUS UNITS ARE psi)

   PROPERTIES FOR MATERIAL  1   ********in site

        DENSITY =    0.14000E+03

        YOUNGS MODULUS= 0.5000E+04
        POISSONS RATIO= 0.3500E+00
        CONFINED MOD.= 0.8025E+04
        LATERAL COEFF.= 0.5385E+00

   PROPERTIES FOR MATERIAL  2   ********Footing

        DENSITY =    0.15000E+03

        YOUNGS MODULUS= 0.3122E+07
        POISSONS RATIO= 0.1700E+00
        CONFINED MOD.= 0.3356E+07
        LATERAL COEFF.= 0.2048E+00

   PROPERTIES FOR MATERIAL  3   ********SW95

        DENSITY =    0.14000E+03

   CONTROLS FOR DUNCAN SOIL MODEL
   WITH SELIG HYPERBOLIC BULK MODULUS FORMULATION

         LRFD STRESS CONTROL..........        0

         ENTERING ELEMENT RATIO.......      0.5000


   HYPERBOLIC STRESS-STRAIN PARAMETERS


         SOIL CLASSIFICATION ............SW95
```

COHESION INTERCEPT C 0.0000

FRICTION ANGLE PHIO (DEG)..... 48.0000

10-FOLD REDUCTION IN PHIO(DEG).. 8.0000

SCALED MODULUS NUMBER ZK 950.0000

MODULUS EXPONENT ZN 0.6000

FAILURE RATIO RF 0.7000

INIT. BULK MODULUS NUMBER BI.... 74.8000

ULT. VOLUMETRIC STRAIN EU 0.0200

INTERFACE ELEMENT MATERIAL-GROUP PROPERTIES

MAT. NO.	NORMAL-ANGLE	COEF-FRICTION	TENSILE-RUPTURE	INITIAL-GAP
1	90.00	0.40000	10.00000	0.00000
2	88.11	0.40000	10.00000	0.00000
3	86.22	0.40000	10.00000	0.00000
4	84.32	0.40000	10.00000	0.00000
5	82.43	0.40000	10.00000	0.00000
6	80.54	0.40000	10.00000	0.00000
7	78.65	0.40000	10.00000	0.00000
8	76.76	0.40000	10.00000	0.00000
9	74.87	0.40000	10.00000	0.00000
10	72.97	0.40000	10.00000	0.00000
11	71.08	0.40000	10.00000	0.00000
12	69.19	0.40000	10.00000	0.00000
13	67.30	0.40000	10.00000	0.00000
14	65.41	0.40000	10.00000	0.00000
15	10.46	0.40000	10.00000	0.00000
16	5.11	0.40000	10.00000	0.00000
17	0.00	0.40000	10.00000	0.00000
18	0.00	0.40000	10.00000	0.00000
19	0.00	0.40000	10.00000	0.00000

LRFD TOTAL LOAD FACTORS PER LOAD STEP

LOAD STEP	LOAD FACTOR	USER COMMENT
1	1.310	Factor for load step #1
2	0.857	Factor for load step #2
3	0.857	Factor for load step #3
4	0.857	Factor for load step #4
5	1.365	Factor for load step #5
6	1.365	Factor for load step #6
7	1.365	Factor for load step #7

28x10H20c2Mod.out

8	1.365	Factor for load step #8
9	1.500	Factor for load step #9
10	1.750	Factor for load step #10
11	1.750	Factor for load step #11
12	1.750	Factor for load step #12
13	1.750	Factor for load step #13

+ +

SOLUTION OUTPUT RESULTS

+ +

FINITE ELEMENT OUTPUT FOR LOAD STEP 13

+ +

CONCRETE, FACTORED-EVALUATION FOR GROUP 1, LOAD-STEP 13

STRUCTURAL RESPONSES OF CONCRETE-GROUP 1, LOAD-STEP 13
COORDINATES, DISPLACEMENTS AND CRACK DEPTHS ARE INCHES
Y-BAR IS "NEUTRAL AXIS" LOCATION FROM INTERIOR, INCHES
PRESSURES ARE LB/IN**2
MOMENTS ARE IN-LB/IN
THRUST AND SHEAR ARE LB/IN

LOCAL NODE	X-COORD. Y-COORD.	X-DISP. Y-DISP.	N-PRES. S-PRES.	MOMENT THRUST	Y-BAR CRACK DEPTH
1	0.00	0.00000E+00	-0.40052E+01	0.23345E+05	0.66148E+01
	125.00	-0.18318E+01	-0.93825E-01	-0.15753E+04	0.60171E+01
2	13.42	-0.62226E-03	-0.34066E+01	0.23295E+05	0.66148E+01
	124.78	-0.18212E+01	-0.15061E-01	-0.15761E+04	0.60152E+01
3	26.80	0.18799E-03	-0.28081E+01	0.23174E+05	0.65476E+01
	124.11	-0.17894E+01	0.63703E-01	-0.15766E+04	0.59946E+01
4	40.15	0.38113E-02	-0.23078E+01	0.23091E+05	0.65476E+01
	123.01	-0.17368E+01	0.79018E+00	-0.15720E+04	0.59940E+01
5	53.46	0.11591E-01	-0.79748E+01	0.23134E+05	0.65476E+01
	121.47	-0.16635E+01	0.30434E+01	-0.15482E+04	0.59974E+01
6	66.71	0.24885E-01	-0.19481E+02	0.22277E+05	0.65476E+01
	119.48	-0.15701E+01	0.61904E+01	-0.14914E+04	0.59947E+01

7	79.89	0.44777E-01	-0.23386E+02	0.18427E+05	0.65930E+01
	117.06	-0.14584E+01	-0.38984E+00	-0.14646E+04	0.59090E+01
8	92.98	0.71527E-01	-0.25549E+02	0.10870E+05	0.65930E+01
	114.21	-0.13333E+01	-0.10185E+02	-0.15568E+04	0.51732E+01
9	105.97	0.10437E+00	-0.30244E+02	-0.73580E+03	0.42126E+01
	110.92	-0.12011E+01	-0.12057E+02	-0.17378E+04	0.11680E+01
10	118.85	0.14081E+00	-0.54189E+01	-0.17156E+05	0.30809E+01
	107.21	-0.10716E+01	-0.21407E+01	-0.18740E+04	0.67149E+01
11	131.59	0.17672E+00	-0.61930E+01	-0.33884E+05	0.34674E+01
	103.08	-0.95796E+00	-0.24605E+01	-0.19504E+04	0.82341E+01
12	144.19	0.20930E+00	-0.61085E+01	-0.51046E+05	0.40809E+01
	98.53	-0.86528E+00	-0.24376E+01	-0.20310E+04	0.10393E+02
13	156.64	0.23818E+00	-0.76096E+01	-0.68632E+05	0.45666E+01
	93.56	-0.79087E+00	-0.30543E+01	-0.21191E+04	0.13475E+02
14	168.91	0.26440E+00	-0.84770E+01	-0.86934E+05	0.57315E+01
	88.19	-0.72924E+00	-0.89973E+01	-0.23682E+04	0.19526E+02
15	171.76	0.31637E+00	-0.58217E+01	-0.76025E+05	0.47460E+01
	75.95	-0.71635E+00	-0.28088E+01	-0.25543E+04	0.12791E+02
16	173.47	0.35516E+00	-0.94688E+01	-0.63098E+05	0.38144E+01
	63.50	-0.71013E+00	-0.38908E+01	-0.25196E+04	0.93013E+01
17	174.00	0.36974E+00	-0.12327E+02	-0.48707E+05	0.34594E+01
	50.94	-0.70846E+00	-0.74463E+00	-0.24905E+04	0.80956E+01
18	174.00	0.34574E+00	-0.85104E+01	-0.30584E+05	0.34814E+01
	33.96	-0.70695E+00	0.22731E+01	-0.24698E+04	0.77011E+01
19	174.00	0.28621E+00	-0.26168E+01	-0.14915E+05	0.36437E+01
	16.98	-0.70560E+00	0.72349E+00	-0.24621E+04	0.67591E+01
20	174.00	0.21257E+00	0.32769E+01	0.18713E-09	0.61687E+01
	0.00	-0.70475E+00	-0.82616E+00	-0.24675E+04	0.00000E+00

SHEAR FORCE DIAGNOSTCS FOR CONCRETE-GROUP 1, LOAD STEP 13
-- V-factor is coefficient of sqrt(PFPC) equal to capacity.
-- Shear depth "d" is negative if measured from outer wall.
-- Stirrup load is excess shear force above capacity.

NODE	EQUIVALENT V-factor	SHEAR CAPACITY lbs/inch	APPLIED SHEAR lbs/inch	APPLIED/ CAPACITY ratio	SHEAR DEPTH-d inches	STIRRUP LOAD lbs/inch
1	2.80	1807.38	1.01	0.001	8.00	0.00
2	2.80	1807.45	6.38	0.004	8.00	0.00
3	2.80	1807.49	7.61	0.004	8.00	0.00
4	2.80	1807.10	1.48	0.001	8.00	0.00
5	2.80	1805.11	30.40	0.017	8.00	0.00
6	2.79	1800.35	175.68	0.098	8.00	0.00
7	2.77	1800.06	425.63	0.236	8.06	0.00
8	4.25	2764.78	715.07	0.259	8.06	0.00

9	4.50	2764.55	1045.90	0.378	-7.63	0.00
10	4.05	2672.87	1237.01	0.463	-8.19	0.00
11	2.49	1985.57	1264.65	0.637	-9.88	0.00
12	1.91	1957.46	1296.67	0.662	-12.69	0.00
13	1.67	2249.88	1339.24	0.595	-16.69	0.00
14	1.44	2854.83	248.70	0.087	-24.56	0.00
15	1.71	2189.19	-948.46	0.433	-15.88	0.00
16	2.08	1861.81	-1086.48	0.584	-11.13	0.00
17	2.29	1766.22	-1106.00	0.626	-9.56	0.00
18	2.35	1811.12	-995.09	0.549	-9.56	0.00
19	3.84	2961.07	-900.62	0.304	-9.56	0.00
20	4.50	3625.40	-856.19	0.236	10.00	0.00

STRESS AND STRAIN MEASURES FOR CONCRETE-GROUP 1, LOAD STEP 13

NODE	MAXIMUM COMPRESSION psi	AVERAGE SHEAR psi	RADIAL TENSION psi	INNER-WALL STRAIN in/in	OUTER-WALL STRAIN in/in
1	-2182.45	0.13	7.53	0.7218E-03	-0.4612E-03
2	-2178.67	0.82	7.51	0.7201E-03	-0.4604E-03
3	-2168.54	0.98	7.43	0.7108E-03	-0.4582E-03
4	-2160.97	0.19	7.38	0.7082E-03	-0.4566E-03
5	-2157.71	3.91	7.40	0.7082E-03	-0.4560E-03
6	-2072.33	22.58	7.10	0.6804E-03	-0.4379E-03
7	-1680.99	54.26	5.49	0.5295E-03	-0.3552E-03
8	-1003.15	91.16	2.40	0.2448E-03	-0.2120E-03
9	-1003.15	133.33	0.00	-0.7279E-04	0.9558E-05
10	-1771.85	147.15	0.00	-0.3744E-03	0.6702E-03
11	-2381.89	125.28	0.00	-0.5033E-03	0.1046E-02
12	-2349.24	100.47	0.00	-0.4964E-03	0.1122E-02
13	-2033.84	79.22	0.00	-0.4298E-03	0.1059E-02
14	-1449.07	10.04	0.00	-0.3062E-03	0.8361E-03
15	-2464.05	-58.93	0.00	-0.5207E-03	0.1239E-02
16	-3413.63	-95.77	0.00	-0.7529E-03	0.1675E-02
17	-3415.35	-113.07	0.00	-0.7536E-03	0.1593E-02
18	-2471.69	-101.73	0.00	-0.5223E-03	0.9636E-03
19	-1355.96	-92.08	0.00	-0.2865E-03	0.3924E-03
20	-184.87	-87.53	0.00	-0.3907E-04	-0.3907E-04

STEEL STRESS AND CRACK WIDTHS FOR CONCRETE-GROUP 1, LOAD STEP 13
NOTE: CRACK WIDTH IS REDUCED TO SERVICE-LOAD LEVEL.
ALL OTHER RESPONSES ARE AT FACTORED LOAD LEVEL.

NODE	INNER CAGE psi	OUTER CAGE psi	MAX STRESS TO YIELD ratio	CRACK WIDTH inches
1	15463.08	-5507.70	0.2577	0.00029
2	15423.53	-5502.06	0.2571	0.00026
3	15200.50	-5522.56	0.2533	0.00014
4	15145.18	-5503.98	0.2524	0.00005
5	15148.58	-5487.71	0.2525	0.00000
6	14554.93	-5268.81	0.2426	0.00000
7	11271.03	-4490.70	0.1879	0.00000
8	4909.46	-3229.06	0.0818	0.00000
9	-1798.14	-331.06	0.0300	0.00000
10	-5665.88	13720.24	0.2287	0.00000

11	-8019.05	23566.38	0.3928	0.00000
12	-8999.80	27447.67	0.4575	0.00000
13	-8735.30	27697.39	0.4616	0.00000
14	-7061.83	23358.91	0.3893	0.00000
15	-10468.34	32026.45	0.5338	0.00000
16	-12583.79	39475.30	0.6579	0.00455
17	-11550.48	35582.90	0.5930	0.00400
18	-8752.86	21089.28	0.3515	0.00000
19	-5525.11	8111.10	0.1352	0.00000
20	-1244.99	-1244.99	0.0207	0.00000

ASSESSMENT SUMMARY CONCRETE-GROUP 1, LOAD-STEP 13

LRFD SUMMARY EVALUATION FOR GROUP 1, LOAD STEP 13

DESIGN-CRITERION	CONTROL NODE	FACTORED DEMAND	FACTORED CAPACITY	RATIO VALUE
STEEL YIELDING (psi)	16	39475.3	60000.0	0.658
CONCRETE CRUSHING (psi)	17	3415.4	4875.0	0.701
SHEAR FAILURE (lbs/in)	12	1296.7	1761.7	0.736
RADIAL-TENSION FAIL (psi)	1	7.5	69.6	0.108

LRFD SERVICE-LOAD PERFORMANCE MEASURES FOR GROUP 1, LOAD STEP 13

NODE NUMBER FOR MAXIMUM CRACK WIDTH 16

MAXIMUM CRACK WIDTH AT SERVICE LOAD (inches) 0.00455

LRFD RATIO: MAX-CRACK-WIDTH / ALLOWABLE 0.45

SPAN LENGTH FOR AUXILIARY EQUATIONS (inches)..... 348.00

* * * * NORMAL EXIT FROM CANDE * * * *

28x10_3S2c1Mod.out

```
*** WELCOME TO CANDE-2013(version 3/1/2013) ***

MASTER CONTROL AND PIPE-TYPE DATA FOR PROBLEM #  1

     USER TITLE: 28x10

     EXECUTION MODE ..................   ANALYS

     SOLUTION LEVEL ..................  #2 AUTO

     METHODOLOGY (LRFD OR SERVICE) ...     LRFD

     NUMBER OF PIPE-ELEMENT GROUPS ....       1

     MAXIMUM ITERATIONS PER STEP ......      30


     CULVERT PIPE-TYPE ............... CONCRETE

     CANNED MESH CODE # ..............        3

     NUMBER OF BEAM ELEMENTS .........       19

     CONCRETE MATERIAL PROPERTIES ARE AS FOLLOWS

          COMPRESSION STRENGTH (psi)..........       6500.000

          ELASTIC YOUNGS MODULUS (psi)........    4595487.000

          POISSON RATIO ......................          0.170

          CONCRETE DENSITY (pcf) .............        150.000

          INITIAL TENSILE CRACKING STRAIN.....       0.000010

          INITIAL COMPRESSION YIELD STRAIN....       0.000687

          INITIAL COMPRESSION CRUSH STRAIN ...       0.002000

          SHEAR STRENGTH MODEL (NSHEAR) # ...          1
          (VARIABLE STRENGTH MODEL PRINTED IN OUTPUT)

          CONCRETE CRACK-WIDTH MODEL NAME.....   HEGER-McGRATH
          (DRIVEN BY TENSILE STRAIN IN STEEL)

     STEEL REINFORCEMENT MATERIAL PROPERTIES

          TYPE OF STEEL CAGES (RSHAPE) .......     ARBIT

          STEEL YIELD STRENGTH (psi)..........      60000.000

          STEEL ELASTIC MODULUS (psi).........   29000000.000
```

STEEL POISSON RATIO 0.300000

STEEL YIELDING STRAIN 0.001883

NONLINEAR MODELING CODE (1,2,3) 3

STEEL-BASED CRACKWIDTH PREDICTION PARAMETERS

REBAR SPACING INNER ROW (SLI), (in)	4.00
REBAR SPACING OUTER ROW (SLO), (in)	4.00
NUMBER OF STEEL LAYERS FOR INNER CAGE	1
NUMBER OF STEEL LAYERS FOR OUTER CAGE	1
HEGER-MCGRATH CODE NUMBER FOR STEEL TYPE..	3

WALL THICKNESS, REBAR AREAS AND COVER DEPTHS

WALL-THICK	INNER-REBAR	OUTER-REBAR	INNER-COVER	OUTER COVER
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1100	0.1500	2.0000	2.4375
10.6250	0.1100	0.1500	2.0000	2.4375
12.3130	0.1100	0.1500	2.0000	2.4375
15.1250	0.1100	0.1500	2.0000	2.4375
19.1250	0.1100	0.1500	2.0000	2.4375
27.0000	0.1100	0.1500	2.0000	2.4375
18.3130	0.1100	0.1500	2.0000	2.4375
13.5630	0.1100	0.1500	2.0000	2.4375
12.0000	0.1100	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375

LRFD RESISTANCE FACTORS FOR STRENGTH-LIMIT STATES
AND CRACK-WIDTH LIMIT AT SERVICE LOAD

YIELDING OF REINFORCEMENT STEEL	1.000
CRUSHING OF CONCRETE OUTER FIBER.....	0.750
SHEARING FAILURE OF CONCRETE	0.900
SPLITTING OF CONCRETE IN RADIAL TENSION	0.900
ALLOWABLE CRACKWIDTH SERVICE LOAD (inch)....	0.010

LARGE DEFORMATION/BUCKLING CODE, IBUCK = 0
IBUCK=0, MEANS SMALL DEFORMATION THEORY FOR GROUP
AND NO BUCKLING PREDICTION.

28x10_3S2c1Mod.out

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


 REVIEW SYSTEM INPUT DATA


 LEVEL-2 DATA FOR ARCH-TYPE CANNED MESH


    *** MESH PARAMETERS ***
     TYPE OF MESH ------------------------------------- TREN
     DEPTH OF TRENCH ABOVE FOOTING LEVEL (FT) ---------   12.42
     WIDTH OF TRENCH AT FOOTING LEVEL (FT) ------------    5.00
     SLOPE OF TRENCH WALL (H/V) -----------------------    0.00
     MESH SPACING PARAMETER ---------------------------    1.00
     TOTAL SOIL HEIGHT ABOVE CROWN (FT) ---------------    2.00
     MESH HEIGHT ABOVE CROWN (FT) ----------------------    2.00
     SOIL DENSITY ABOVE MESH (PCF) --------------------  140.00
     NUMBER OF ELEMENT LAYERS ABOVE CROWN -------------    3


*** ARCH PARAMETERS ***
     CENTERLINE RISE OF ARCH (IN) ----------------------  125.00
     BOTTOM HALF SPAN OF ARCH (IN) ---------------------  174.00
     SIDE RISE OF ARCH ABOVE FOOTING (IN) -------------   50.94
     FOOTING DEPTH (IN) --------------------------------   24.00
     OUTSIDE FOOTING WIDTH (IN) ------------------------   30.00
     INSIDE FOOTING WIDTH (IN) -------------------------   30.00
     NUMBER OF ARCH SEGMENTS DEFINED -------------------    3

*** CURVED TOP SEGMENT ***
     RADIUS (IN) ---------------------------------------  405.88
     CENTRAL ANGLE (DEG) -------------------------------   24.59
     SEGMENT ARC LENGTH (IN) ---------------------------  174.19
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------   13

*** CURVED CORNER SEGMENT ***
     RADIUS (IN) ---------------------------------------  133.94
     CENTRAL ANGLE (DEG) -------------------------------   16.14
     SEGMENT ARC LENGTH (IN) ---------------------------   37.73
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

*** STRAIGHT SIDE SEGMENT ***
     DEFLECTION ANGLE (DEG) ----------------------------   90.00
     SEGMENT LENGTH (IN) -------------------------------   50.94
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

 FINITE ELEMENT INPUT CONTROLS (PREP)


THE DATA TO BE RUN IS ENTITLED ...

New Level 2 arch mesh

PRINT AND PLOT CONTROL CODES ...
  PRINT CONTROL FOR MESH DATA------------    1
  PLOT FILE CONTROL MESH & RESULS--------    3
  PRINT FINITE ELEMENT RESULTS ----------    1
  INPUT DATA CHECK CODE------------------    0
```

28x10_3S2c1Mod.out

```
KEY NUMBERS DESCRIBING MESH ...
  THE NUMBER OF LOAD STEPS IS------------   13
  TOTAL NUMBER OF NODES IS---------------  244
  TOTAL NUMBER OF ELEMENTS IS------------  209
  TOTAL NUMBER OF BEAM ELEMENTS IS-------   19
  MAX NUMBER OF BOUNDARY CONDITIONS IS---   36



 EXTENDED LEVEL-2: CHANGES TO CANNED MESH

          * NUMBER OF NODES TO BE CHANGED -------      0 *
          * NUMBER OF ELEMENTS TO BE CHANGED ----      0 *
          * ADDITIONAL BOUNDARY CONDITIONS ------     31 *



 * * * BOUNDARY CONDITIONS * * *
  (FORCES = LBS; DISPLACEMENTS = INCHES; ROTATIONS = DEGREES)

  BOUNDARY      LOAD      X-FORCE     OR      Y-FORCE     OR      X-Y ROTATION
BEAM ROTATIONAL
     NODE       STEP      X-DISPLACEMENT      Y-DISPLACEMENT
BOUNDARY CONDITIONS

      225        10    F =   0.0000E+00    F =  -0.7438E+02      0.0000E+00
     F
      225        11    F =   0.0000E+00    F =  -0.7438E+02      0.0000E+00
     F
      225        12    F =   0.0000E+00    F =  -0.7438E+02      0.0000E+00
     F
      225        13    F =   0.0000E+00    F =  -0.7438E+02      0.0000E+00
     F
      232        10    F =   0.0000E+00    F =  -0.7438E+02      0.0000E+00
     F
      232        11    F =   0.0000E+00    F =  -0.7438E+02      0.0000E+00
     F
      232        12    F =   0.0000E+00    F =  -0.7438E+02      0.0000E+00
     F
      232        13    F =   0.0000E+00    F =  -0.7438E+02      0.0000E+00
     F
      224        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      225        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      226        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      227        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      228        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
```

```
F
 231        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 232        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 233        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 224         9    F =   0.0000E+00    F =  -0.2188E+01      0.0000E+00
F
 225         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 226         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 227         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 228         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 229         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 230         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 231         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 232         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 233         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 234         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 235         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 236         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F

* * * * * COMPLETED MESH GENERATION  * * * * *

New Level 2 arch mesh

CALCULATED KEY NUMBERS ...
  THE NUMBER OF DATA ERRORS IS-----------    0
  THE NUMBER OF SOIL MATERIALS IS--------    3
  THE NUMBER OF PIPE-TYPE GROUPS IS------    1
  THE NUMBER OF INTERFACE MATERIALS IS---   19
  BAND WIDTH ESTIMATE (MAX)--------------   88


* * * * MESH DATA HAS BEEN SAVED ON UNIT 14 * * * *


 BEAM-NODE SEQUENCE NUMBERS FOR EACH GROUP


    BEAM-ELEMENT GROUP NUMBER =    1

     BEAM-NODE       MESH-NODE      CONNECTED-GROUP-ELEMENTS
     SEQUENCE        NUMBER         FOREWARD-#    BACKWARD-#
         1             198              1              0
         2             194              2              1
         3             190              3              2
         4             167              4              3
```

5	164	5	4
6	161	6	5
7	158	7	6
8	138	8	7
9	136	9	8
10	134	10	9
11	132	11	10
12	130	12	11
13	128	13	12
14	118	14	13
15	115	15	14
16	109	16	15
17	103	17	16
18	97	18	17
19	91	19	18
20	80	0	19

```
MATERIAL DESCRIPTION FOR SOILS AND INTERFACE
(ALL DENSITY UNITS ARE pcf, ALL MODULUS UNITS ARE psi)

   PROPERTIES FOR MATERIAL  1   ********in site

        DENSITY =    0.14000E+03

        YOUNGS MODULUS= 0.5000E+04
        POISSONS RATIO= 0.3500E+00
        CONFINED MOD.= 0.8025E+04
        LATERAL COEFF.= 0.5385E+00

   PROPERTIES FOR MATERIAL  2   ********Footing

        DENSITY =    0.15000E+03

        YOUNGS MODULUS= 0.3122E+07
        POISSONS RATIO= 0.1700E+00
        CONFINED MOD.= 0.3356E+07
        LATERAL COEFF.= 0.2048E+00

   PROPERTIES FOR MATERIAL  3   ********SW95

        DENSITY =    0.14000E+03

   CONTROLS FOR DUNCAN SOIL MODEL
   WITH SELIG HYPERBOLIC BULK MODULUS FORMULATION

         LRFD STRESS CONTROL..........       0

         ENTERING ELEMENT RATIO.......      0.5000


   HYPERBOLIC STRESS-STRAIN PARAMETERS


         SOIL CLASSIFICATION ............SW95
```

COHESION INTERCEPT C 0.0000

FRICTION ANGLE PHIO (DEG)..... 48.0000

10-FOLD REDUCTION IN PHIO(DEG).. 8.0000

SCALED MODULUS NUMBER ZK 950.0000

MODULUS EXPONENT ZN 0.6000

FAILURE RATIO RF 0.7000

INIT. BULK MODULUS NUMBER BI.... 74.8000

ULT. VOLUMETRIC STRAIN EU 0.0200

INTERFACE ELEMENT MATERIAL-GROUP PROPERTIES

MAT. NO.	NORMAL-ANGLE	COEF-FRICTION	TENSILE-RUPTURE	INITIAL-GAP
1	90.00	0.40000	10.00000	0.00000
2	88.11	0.40000	10.00000	0.00000
3	86.22	0.40000	10.00000	0.00000
4	84.32	0.40000	10.00000	0.00000
5	82.43	0.40000	10.00000	0.00000
6	80.54	0.40000	10.00000	0.00000
7	78.65	0.40000	10.00000	0.00000
8	76.76	0.40000	10.00000	0.00000
9	74.87	0.40000	10.00000	0.00000
10	72.97	0.40000	10.00000	0.00000
11	71.08	0.40000	10.00000	0.00000
12	69.19	0.40000	10.00000	0.00000
13	67.30	0.40000	10.00000	0.00000
14	65.41	0.40000	10.00000	0.00000
15	10.46	0.40000	10.00000	0.00000
16	5.11	0.40000	10.00000	0.00000
17	0.00	0.40000	10.00000	0.00000
18	0.00	0.40000	10.00000	0.00000
19	0.00	0.40000	10.00000	0.00000

LRFD TOTAL LOAD FACTORS PER LOAD STEP

LOAD STEP	LOAD FACTOR	USER COMMENT
1	1.310	Factor for load step #1
2	0.857	Factor for load step #2
3	0.857	Factor for load step #3
4	0.857	Factor for load step #4
5	1.365	Factor for load step #5
6	1.365	Factor for load step #6
7	1.365	Factor for load step #7

28x10_3S2c1Mod.out

8	1.365	Factor for load step #8
9	1.500	Factor for load step #9
10	1.350	Factor for load step #10
11	1.350	Factor for load step #11
12	1.350	Factor for load step #12
13	1.350	Factor for load step #13

+ +

SOLUTION OUTPUT RESULTS

+ +

FINITE ELEMENT OUTPUT FOR LOAD STEP 13

+ +

CONCRETE, FACTORED-EVALUATION FOR GROUP 1, LOAD-STEP 13

STRUCTURAL RESPONSES OF CONCRETE-GROUP 1, LOAD-STEP 13
COORDINATES, DISPLACEMENTS AND CRACK DEPTHS ARE INCHES
Y-BAR IS "NEUTRAL AXIS" LOCATION FROM INTERIOR, INCHES
PRESSURES ARE LB/IN**2
MOMENTS ARE IN-LB/IN
THRUST AND SHEAR ARE LB/IN

LOCAL NODE	X-COORD. Y-COORD.	X-DISP. Y-DISP.	N-PRES. S-PRES.	MOMENT THRUST	Y-BAR CRACK DEPTH
1	0.00	0.00000E+00	-0.19034E+02	0.31855E+05	0.66148E+01
	125.00	-0.16235E+01	0.34248E+01	-0.11014E+04	0.62911E+01
2	13.42	-0.31624E-03	-0.15163E+02	0.30757E+05	0.66148E+01
	124.78	-0.16091E+01	-0.50124E+00	-0.11141E+04	0.62761E+01
3	26.80	0.12065E-02	-0.11293E+02	0.27272E+05	0.66148E+01
	124.11	-0.15672E+01	-0.44273E+01	-0.11559E+04	0.62213E+01
4	40.15	0.61096E-02	-0.72674E+01	0.22116E+05	0.66148E+01
	123.01	-0.15009E+01	-0.28263E+01	-0.12177E+04	0.61073E+01
5	53.46	0.15490E-01	-0.37219E+01	0.16038E+05	0.65476E+01
	121.47	-0.14150E+01	-0.14176E+01	-0.12621E+04	0.58761E+01
6	66.71	0.29841E-01	-0.16215E+01	0.96960E+04	0.65476E+01
	119.48	-0.13153E+01	-0.58664E+00	-0.12926E+04	0.54116E+01

7	79.89	0.49013E-01	-0.34263E+01	0.34809E+04	0.61375E+01
	117.06	-0.12081E+01	-0.13170E+01	-0.13229E+04	0.36983E+01
8	92.98	0.72326E-01	-0.43253E+01	-0.29191E+04	0.48019E+01
	114.21	-0.10994E+01	-0.16856E+01	-0.13614E+04	0.00000E+00
9	105.97	0.98731E-01	-0.76079E+01	-0.96452E+04	0.29481E+01
	110.92	-0.99315E+00	-0.27106E+01	-0.14107E+04	0.60958E+01
10	118.85	0.12591E+00	-0.10905E+02	-0.17266E+05	0.30809E+01
	107.21	-0.89629E+00	-0.27702E+01	-0.14700E+04	0.68760E+01
11	131.59	0.15122E+00	-0.10179E+02	-0.26358E+05	0.34674E+01
	103.08	-0.81591E+00	0.11508E+01	-0.15074E+04	0.82148E+01
12	144.19	0.17360E+00	-0.16293E+02	-0.36796E+05	0.40809E+01
	98.53	-0.75207E+00	-0.65111E+01	-0.15753E+04	0.10314E+02
13	156.64	0.19315E+00	-0.11749E+02	-0.49688E+05	0.49117E+01
	93.56	-0.70149E+00	-0.41557E+01	-0.16857E+04	0.13302E+02
14	168.91	0.21069E+00	-0.11535E+02	-0.64231E+05	0.57315E+01
	88.19	-0.66013E+00	-0.94305E+01	-0.19229E+04	0.19269E+02
15	171.76	0.24499E+00	-0.72082E+01	-0.55961E+05	0.47460E+01
	75.95	-0.65153E+00	-0.26214E+01	-0.21047E+04	0.12673E+02
16	173.47	0.26953E+00	-0.87331E+01	-0.46419E+05	0.37441E+01
	63.50	-0.64741E+00	-0.27437E+01	-0.20861E+04	0.92347E+01
17	174.00	0.27628E+00	-0.97623E+01	-0.35809E+05	0.33970E+01
	50.94	-0.64626E+00	-0.64392E+00	-0.20688E+04	0.80279E+01
18	174.00	0.25339E+00	-0.63341E+01	-0.22452E+05	0.34814E+01
	33.96	-0.64501E+00	0.14967E+01	-0.20601E+04	0.75717E+01
19	174.00	0.20461E+00	-0.21158E+01	-0.10921E+05	0.36437E+01
	16.98	-0.64391E+00	0.52333E+00	-0.20606E+04	0.64355E+01
20	174.00	0.14566E+00	0.21026E+01	0.15075E-09	0.61687E+01
	0.00	-0.64321E+00	-0.45005E+00	-0.20694E+04	0.00000E+00

SHEAR FORCE DIAGNOSTCS FOR CONCRETE-GROUP 1, LOAD STEP 13
-- V-factor is coefficient of sqrt(PFPC) equal to capacity.
-- Shear depth "d" is negative if measured from outer wall.
-- Stirrup load is excess shear force above capacity.

NODE	EQUIVALENT V-factor	SHEAR CAPACITY lbs/inch	APPLIED SHEAR lbs/inch	APPLIED/ CAPACITY ratio	SHEAR DEPTH-d inches	STIRRUP LOAD lbs/inch
1	2.74	1767.68	-7.29	0.004	8.00	0.00
2	2.74	1768.75	170.98	0.097	8.00	0.00
3	2.75	1772.24	322.47	0.182	8.00	0.00
4	2.76	1777.42	419.23	0.236	8.00	0.00
5	2.76	1781.14	463.46	0.260	8.00	0.00
6	3.41	2200.93	468.58	0.213	8.00	0.00
7	4.50	2923.16	470.75	0.161	8.06	0.00
8	4.50	2764.55	489.82	0.177	-7.63	0.00
9	3.51	2159.20	535.40	0.248	-7.63	0.00

10	2.46	1620.62	623.67	0.385	-8.19	0.00
11	2.16	1719.51	728.77	0.424	-9.88	0.00
12	1.86	1906.84	870.58	0.457	-12.69	0.00
13	1.73	2324.07	1023.80	0.441	-16.69	0.00
14	1.43	2832.28	213.50	0.075	-24.56	0.00
15	1.69	2164.07	-708.75	0.328	-15.88	0.00
16	2.05	1834.59	-801.47	0.437	-11.13	0.00
17	2.25	1738.10	-815.28	0.469	-9.56	0.00
18	2.34	1807.38	-732.89	0.406	-9.56	0.00
19	3.87	2982.79	-661.15	0.222	-9.56	0.00
20	4.50	3625.40	-625.23	0.172	10.00	0.00

STRESS AND STRAIN MEASURES FOR CONCRETE-GROUP 1, LOAD STEP 13

NODE	MAXIMUM COMPRESSION psi	AVERAGE SHEAR psi	RADIAL TENSION psi	INNER-WALL STRAIN in/in	OUTER-WALL STRAIN in/in
1	-2786.63	-0.94	10.90	0.1026E-02	-0.5889E-03
2	-2699.84	21.97	10.49	0.9884E-03	-0.5705E-03
3	-2423.16	41.44	9.24	0.8695E-03	-0.5121E-03
4	-2014.89	53.88	7.30	0.6937E-03	-0.4258E-03
5	-1525.89	59.56	5.02	0.4837E-03	-0.3224E-03
6	-1002.86	60.22	2.72	0.2717E-03	-0.2119E-03
7	-422.39	60.01	0.37	0.5186E-04	-0.8926E-04
8	-254.64	62.44	0.00	-0.5381E-04	0.8299E-05
9	-1159.89	68.25	0.00	-0.2451E-03	0.4020E-03
10	-1708.07	74.19	0.00	-0.3609E-03	0.6904E-03
11	-1851.24	72.20	0.00	-0.3912E-03	0.8142E-03
12	-1708.88	67.45	0.00	-0.3611E-03	0.8056E-03
13	-1499.99	60.56	0.00	-0.3170E-03	0.7570E-03
14	-1088.98	8.62	0.00	-0.2301E-03	0.6085E-03
15	-1840.63	-44.04	0.00	-0.3890E-03	0.9065E-03
16	-2640.21	-70.65	0.00	-0.5579E-03	0.1222E-02
17	-2645.01	-83.35	0.00	-0.5589E-03	0.1160E-02
18	-1856.55	-74.93	0.00	-0.3923E-03	0.6979E-03
19	-1015.25	-67.59	0.00	-0.2145E-03	0.2697E-03
20	-155.05	-63.92	0.00	-0.3276E-04	-0.3276E-04

STEEL STRESS AND CRACK WIDTHS FOR CONCRETE-GROUP 1, LOAD STEP 13
NOTE: CRACK WIDTH IS REDUCED TO SERVICE-LOAD LEVEL.
ALL OTHER RESPONSES ARE AT FACTORED LOAD LEVEL.

NODE	INNER CAGE psi	OUTER CAGE psi	MAX STRESS TO YIELD ratio	CRACK WIDTH inches
1	22398.77	-6223.53	0.3733	0.00364
2	21562.14	-6072.05	0.3594	0.00331
3	18903.72	-5586.48	0.3151	0.00227
4	14971.89	-4872.76	0.2495	0.00073
5	10276.44	-4013.75	0.1713	0.00000
6	5577.17	-2996.50	0.0930	0.00000
7	758.98	-1755.15	0.0293	0.00000
8	-1321.46	-214.96	0.0220	0.00000
9	-3712.52	7815.47	0.1303	0.00000
10	-5196.14	14314.27	0.2386	0.00000
11	-6227.17	18342.67	0.3057	0.00000

12	-6591.54	19680.92	0.3280	0.00000
13	-6522.27	19761.08	0.3294	0.00000
14	-5353.78	16979.58	0.2830	0.00000
15	-7886.60	23393.24	0.3899	0.00000
16	-9416.92	28740.89	0.4790	0.00236
17	-8682.97	25836.87	0.4306	0.00200
18	-6711.92	15183.71	0.2531	0.00000
19	-4265.08	5459.85	0.0910	0.00000
20	-1044.15	-1044.15	0.0174	0.00000

ASSESSMENT SUMMARY CONCRETE-GROUP 1, LOAD-STEP 13

LRFD SUMMARY EVALUATION FOR GROUP 1, LOAD STEP 13

DESIGN-CRITERION	CONTROL NODE	FACTORED DEMAND	FACTORED CAPACITY	RATIO VALUE
STEEL YIELDING (psi)	16	28740.9	60000.0	0.479
CONCRETE CRUSHING (psi)	1	2786.6	4875.0	0.572
SHEAR FAILURE (lbs/in)	17	815.3	1564.3	0.521
RADIAL-TENSION FAIL (psi)	1	10.9	69.6	0.157

LRFD SERVICE-LOAD PERFORMANCE MEASURES FOR GROUP 1, LOAD STEP 13

NODE NUMBER FOR MAXIMUM CRACK WIDTH 1

MAXIMUM CRACK WIDTH AT SERVICE LOAD (inches) 0.00364

LRFD RATIO: MAX-CRACK-WIDTH / ALLOWABLE 0.36

SPAN LENGTH FOR AUXILIARY EQUATIONS (inches)..... 348.00

* * * * NORMAL EXIT FROM CANDE * * * *

28x10_3S2c2Mod.out

```
*** WELCOME TO CANDE-2013(version 3/1/2013) ***

MASTER CONTROL AND PIPE-TYPE DATA FOR PROBLEM #  1

        USER TITLE: 28x10

        EXECUTION MODE ..................   ANALYS

        SOLUTION LEVEL ..................  #2 AUTO

        METHODOLOGY (LRFD OR SERVICE) ...     LRFD

        NUMBER OF PIPE-ELEMENT GROUPS ....       1

        MAXIMUM ITERATIONS PER STEP ......      30


        CULVERT PIPE-TYPE ............... CONCRETE

        CANNED MESH CODE # ..............        3

        NUMBER OF BEAM ELEMENTS .........       19

        CONCRETE MATERIAL PROPERTIES ARE AS FOLLOWS

             COMPRESSION STRENGTH (psi)..........       6500.000

             ELASTIC YOUNGS MODULUS (psi)........    4595487.000

             POISSON RATIO ......................          0.170

             CONCRETE DENSITY (pcf) .............        150.000

             INITIAL TENSILE CRACKING STRAIN.....       0.000010

             INITIAL COMPRESSION YIELD STRAIN....       0.000687

             INITIAL COMPRESSION CRUSH STRAIN ...       0.002000

             SHEAR STRENGTH MODEL (NSHEAR) # ...          1
             (VARIABLE STRENGTH MODEL PRINTED IN OUTPUT)

             CONCRETE CRACK-WIDTH MODEL NAME.....   HEGER-McGRATH
             (DRIVEN BY TENSILE STRAIN IN STEEL)

        STEEL REINFORCEMENT MATERIAL PROPERTIES

             TYPE OF STEEL CAGES (RSHAPE) .......     ARBIT

             STEEL YIELD STRENGTH (psi)..........      60000.000

             STEEL ELASTIC MODULUS (psi).........   29000000.000
```

28x10_3S2c2Mod.out

STEEL POISSON RATIO 0.300000

STEEL YIELDING STRAIN 0.001883

NONLINEAR MODELING CODE (1,2,3) 3

STEEL-BASED CRACKWIDTH PREDICTION PARAMETERS
REBAR SPACING INNER ROW (SLI), (in) 4.00
REBAR SPACING OUTER ROW (SLO), (in) 4.00
NUMBER OF STEEL LAYERS FOR INNER CAGE 1
NUMBER OF STEEL LAYERS FOR OUTER CAGE 1
HEGER-MCGRATH CODE NUMBER FOR STEEL TYPE.. 3

WALL THICKNESS, REBAR AREAS AND COVER DEPTHS

WALL-THICK	INNER-REBAR	OUTER-REBAR	INNER-COVER	OUTER COVER
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1100	0.1500	2.0000	2.4375
10.6250	0.1100	0.1500	2.0000	2.4375
12.3130	0.1100	0.1500	2.0000	2.4375
15.1250	0.1100	0.1500	2.0000	2.4375
19.1250	0.1100	0.1500	2.0000	2.4375
27.0000	0.1100	0.1500	2.0000	2.4375
18.3130	0.1100	0.1500	2.0000	2.4375
13.5630	0.1100	0.1500	2.0000	2.4375
12.0000	0.1100	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375

LRFD RESISTANCE FACTORS FOR STRENGTH-LIMIT STATES
AND CRACK-WIDTH LIMIT AT SERVICE LOAD

YIELDING OF REINFORCEMENT STEEL 1.000

CRUSHING OF CONCRETE OUTER FIBER..... 0.750

SHEARING FAILURE OF CONCRETE 0.900

SPLITTING OF CONCRETE IN RADIAL TENSION 0.900

ALLOWABLE CRACKWIDTH SERVICE LOAD (inch).... 0.010

LARGE DEFORMATION/BUCKLING CODE, IBUCK = 0
IBUCK=0, MEANS SMALL DEFORMATION THEORY FOR GROUP
AND NO BUCKLING PREDICTION.

28x10_3S2c2Mod.out

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


 REVIEW SYSTEM INPUT DATA


 LEVEL-2 DATA FOR ARCH-TYPE CANNED MESH


    *** MESH PARAMETERS ***
     TYPE OF MESH ------------------------------------- TREN
     DEPTH OF TRENCH ABOVE FOOTING LEVEL (FT) ---------   12.42
     WIDTH OF TRENCH AT FOOTING LEVEL (FT) ------------    5.00
     SLOPE OF TRENCH WALL (H/V) -----------------------    0.00
     MESH SPACING PARAMETER ---------------------------    1.00
     TOTAL SOIL HEIGHT ABOVE CROWN (FT) ---------------    2.00
     MESH HEIGHT ABOVE CROWN (FT) ----------------------    2.00
     SOIL DENSITY ABOVE MESH (PCF) --------------------  140.00
     NUMBER OF ELEMENT LAYERS ABOVE CROWN -------------    3


*** ARCH PARAMETERS ***
     CENTERLINE RISE OF ARCH (IN) ----------------------  125.00
     BOTTOM HALF SPAN OF ARCH (IN) ---------------------  174.00
     SIDE RISE OF ARCH ABOVE FOOTING (IN) -------------   50.94
     FOOTING DEPTH (IN) --------------------------------   24.00
     OUTSIDE FOOTING WIDTH (IN) ------------------------   30.00
     INSIDE FOOTING WIDTH (IN) -------------------------   30.00
     NUMBER OF ARCH SEGMENTS DEFINED -------------------    3

*** CURVED TOP SEGMENT ***
     RADIUS (IN) ---------------------------------------  405.88
     CENTRAL ANGLE (DEG) -------------------------------   24.59
     SEGMENT ARC LENGTH (IN) ---------------------------  174.19
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------   13

*** CURVED CORNER SEGMENT ***
     RADIUS (IN) ---------------------------------------  133.94
     CENTRAL ANGLE (DEG) -------------------------------   16.14
     SEGMENT ARC LENGTH (IN) ---------------------------   37.73
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

*** STRAIGHT SIDE SEGMENT ***
     DEFLECTION ANGLE (DEG) ----------------------------   90.00
     SEGMENT LENGTH (IN) -------------------------------   50.94
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

 FINITE ELEMENT INPUT CONTROLS (PREP)


THE DATA TO BE RUN IS ENTITLED ...

New Level 2 arch mesh

PRINT AND PLOT CONTROL CODES ...
  PRINT CONTROL FOR MESH DATA------------    1
  PLOT FILE CONTROL MESH & RESULS--------    3
  PRINT FINITE ELEMENT RESULTS ----------    1
  INPUT DATA CHECK CODE------------------    0
```

28x10_3S2c2Mod.out

```
KEY NUMBERS DESCRIBING MESH ...
  THE NUMBER OF LOAD STEPS IS------------   13
  TOTAL NUMBER OF NODES IS---------------  244
  TOTAL NUMBER OF ELEMENTS IS------------  209
  TOTAL NUMBER OF BEAM ELEMENTS IS-------   19
  MAX NUMBER OF BOUNDARY CONDITIONS IS---   36


 EXTENDED LEVEL-2: CHANGES TO CANNED MESH

          * NUMBER OF NODES TO BE CHANGED -------      0 *
          * NUMBER OF ELEMENTS TO BE CHANGED ----      0 *
          * ADDITIONAL BOUNDARY CONDITIONS ------     31 *


 * * * BOUNDARY CONDITIONS * * *
  (FORCES = LBS; DISPLACEMENTS = INCHES; ROTATIONS = DEGREES)

  BOUNDARY      LOAD      X-FORCE     OR      Y-FORCE     OR      X-Y ROTATION
BEAM ROTATIONAL
     NODE       STEP      X-DISPLACEMENT      Y-DISPLACEMENT
BOUNDARY CONDITIONS

      228        10    F =   0.0000E+00    F =  -0.7438E+02      0.0000E+00
     F
      228        11    F =   0.0000E+00    F =  -0.7438E+02      0.0000E+00
     F
      228        12    F =   0.0000E+00    F =  -0.7438E+02      0.0000E+00
     F
      228        13    F =   0.0000E+00    F =  -0.7438E+02      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =  -0.7438E+02      0.0000E+00
     F
      230        11    F =   0.0000E+00    F =  -0.7438E+02      0.0000E+00
     F
      230        12    F =   0.0000E+00    F =  -0.7438E+02      0.0000E+00
     F
      230        13    F =   0.0000E+00    F =  -0.7438E+02      0.0000E+00
     F
      224        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      225        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      226        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      227        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      228        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
```

```
F
 231        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 232        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 233        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 224         9    F =   0.0000E+00    F =  -0.2188E+01      0.0000E+00
F
 225         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 226         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 227         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 228         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 229         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 230         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 231         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 232         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 233         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 234         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 235         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 236         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F

* * * * * COMPLETED MESH GENERATION  * * * * *

New Level 2 arch mesh

CALCULATED KEY NUMBERS ...
  THE NUMBER OF DATA ERRORS IS-----------    0
  THE NUMBER OF SOIL MATERIALS IS--------    3
  THE NUMBER OF PIPE-TYPE GROUPS IS------    1
  THE NUMBER OF INTERFACE MATERIALS IS---   19
  BAND WIDTH ESTIMATE (MAX)--------------   88


* * * * MESH DATA HAS BEEN SAVED ON UNIT 14 * * * *


 BEAM-NODE SEQUENCE NUMBERS FOR EACH GROUP


    BEAM-ELEMENT GROUP NUMBER =    1

     BEAM-NODE       MESH-NODE      CONNECTED-GROUP-ELEMENTS
     SEQUENCE        NUMBER         FOREWARD-#     BACKWARD-#
         1             198              1              0
         2             194              2              1
         3             190              3              2
         4             167              4              3
```

5	164	5	4
6	161	6	5
7	158	7	6
8	138	8	7
9	136	9	8
10	134	10	9
11	132	11	10
12	130	12	11
13	128	13	12
14	118	14	13
15	115	15	14
16	109	16	15
17	103	17	16
18	97	18	17
19	91	19	18
20	80	0	19

```
MATERIAL DESCRIPTION FOR SOILS AND INTERFACE
(ALL DENSITY UNITS ARE pcf, ALL MODULUS UNITS ARE psi)

   PROPERTIES FOR MATERIAL  1   ********in site

        DENSITY =    0.14000E+03

        YOUNGS MODULUS= 0.5000E+04
        POISSONS RATIO= 0.3500E+00
        CONFINED MOD.= 0.8025E+04
        LATERAL COEFF.= 0.5385E+00

   PROPERTIES FOR MATERIAL  2   ********Footing

        DENSITY =    0.15000E+03

        YOUNGS MODULUS= 0.3122E+07
        POISSONS RATIO= 0.1700E+00
        CONFINED MOD.= 0.3356E+07
        LATERAL COEFF.= 0.2048E+00

   PROPERTIES FOR MATERIAL  3   ********SW95

        DENSITY =    0.14000E+03

   CONTROLS FOR DUNCAN SOIL MODEL
   WITH SELIG HYPERBOLIC BULK MODULUS FORMULATION

         LRFD STRESS CONTROL..........       0

         ENTERING ELEMENT RATIO.......      0.5000


   HYPERBOLIC STRESS-STRAIN PARAMETERS


         SOIL CLASSIFICATION ............SW95
```

COHESION INTERCEPT C 0.0000

FRICTION ANGLE PHIO (DEG)..... 48.0000

10-FOLD REDUCTION IN PHIO(DEG).. 8.0000

SCALED MODULUS NUMBER ZK 950.0000

MODULUS EXPONENT ZN 0.6000

FAILURE RATIO RF 0.7000

INIT. BULK MODULUS NUMBER BI.... 74.8000

ULT. VOLUMETRIC STRAIN EU 0.0200

INTERFACE ELEMENT MATERIAL-GROUP PROPERTIES

MAT. NO.	NORMAL-ANGLE	COEF-FRICTION	TENSILE-RUPTURE	INITIAL-GAP
1	90.00	0.40000	10.00000	0.00000
2	88.11	0.40000	10.00000	0.00000
3	86.22	0.40000	10.00000	0.00000
4	84.32	0.40000	10.00000	0.00000
5	82.43	0.40000	10.00000	0.00000
6	80.54	0.40000	10.00000	0.00000
7	78.65	0.40000	10.00000	0.00000
8	76.76	0.40000	10.00000	0.00000
9	74.87	0.40000	10.00000	0.00000
10	72.97	0.40000	10.00000	0.00000
11	71.08	0.40000	10.00000	0.00000
12	69.19	0.40000	10.00000	0.00000
13	67.30	0.40000	10.00000	0.00000
14	65.41	0.40000	10.00000	0.00000
15	10.46	0.40000	10.00000	0.00000
16	5.11	0.40000	10.00000	0.00000
17	0.00	0.40000	10.00000	0.00000
18	0.00	0.40000	10.00000	0.00000
19	0.00	0.40000	10.00000	0.00000

LRFD TOTAL LOAD FACTORS PER LOAD STEP

LOAD STEP	LOAD FACTOR	USER COMMENT
1	1.310	Factor for load step #1
2	0.857	Factor for load step #2
3	0.857	Factor for load step #3
4	0.857	Factor for load step #4
5	1.365	Factor for load step #5
6	1.365	Factor for load step #6
7	1.365	Factor for load step #7

28x10_3S2c2Mod.out

8	1.365	Factor for load step #8
9	1.500	Factor for load step #9
10	1.350	Factor for load step #10
11	1.350	Factor for load step #11
12	1.350	Factor for load step #12
13	1.350	Factor for load step #13

+ +

SOLUTION OUTPUT RESULTS

+ +

FINITE ELEMENT OUTPUT FOR LOAD STEP 13

+ +

CONCRETE, FACTORED-EVALUATION FOR GROUP 1, LOAD-STEP 13

STRUCTURAL RESPONSES OF CONCRETE-GROUP 1, LOAD-STEP 13
COORDINATES, DISPLACEMENTS AND CRACK DEPTHS ARE INCHES
Y-BAR IS "NEUTRAL AXIS" LOCATION FROM INTERIOR, INCHES
PRESSURES ARE LB/IN**2
MOMENTS ARE IN-LB/IN
THRUST AND SHEAR ARE LB/IN

LOCAL NODE	X-COORD. Y-COORD.	X-DISP. Y-DISP.	N-PRES. S-PRES.	MOMENT THRUST	Y-BAR CRACK DEPTH
1	0.00 125.00	0.00000E+00 -0.15257E+01	-0.30340E+01 -0.39322E+00	0.19953E+05 -0.11763E+04	0.66148E+01 0.60689E+01
2	13.42 124.78	-0.44075E-03 -0.15167E+01	-0.29606E+01 -0.31764E+00	0.19853E+05 -0.11814E+04	0.66148E+01 0.60639E+01
3	26.80 124.11	0.31298E-03 -0.14896E+01	-0.28872E+01 -0.24205E+00	0.19588E+05 -0.11863E+04	0.66148E+01 0.60547E+01
4	40.15 123.01	0.34369E-02 -0.14449E+01	-0.48631E+01 0.53075E+00	0.19174E+05 -0.11866E+04	0.66148E+01 0.60413E+01
5	53.46 121.47	0.10052E-01 -0.13831E+01	-0.93269E+01 0.10454E+01	0.18256E+05 -0.11801E+04	0.65476E+01 0.59889E+01
6	66.71 119.48	0.21133E-01 -0.13055E+01	-0.12328E+02 -0.83726E+00	0.16032E+05 -0.11863E+04	0.65476E+01 0.59095E+01

7	79.89	0.37260E-01	-0.14045E+02	0.11966E+05	0.65930E+01
	117.06	-0.12151E+01	-0.30330E+01	-0.12245E+04	0.56524E+01
8	92.98	0.58304E-01	-0.16512E+02	0.57637E+04	0.61238E+01
	114.21	-0.11167E+01	-0.65515E+01	-0.13067E+04	0.39840E+01
9	105.97	0.83442E-01	-0.10636E+02	-0.29764E+04	0.34272E+01
	110.92	-0.10154E+01	-0.39991E+01	-0.14012E+04	0.45824E+01
10	118.85	0.11076E+00	-0.14243E+02	-0.13159E+05	0.30809E+01
	107.21	-0.91819E+00	-0.56723E+01	-0.14949E+04	0.66549E+01
11	131.59	0.13742E+00	-0.69814E+01	-0.25401E+05	0.34674E+01
	103.08	-0.83356E+00	-0.27743E+01	-0.15851E+04	0.81628E+01
12	144.19	0.16156E+00	-0.78436E+01	-0.38381E+05	0.40809E+01
	98.53	-0.76472E+00	-0.31285E+01	-0.16623E+04	0.10312E+02
13	156.64	0.18290E+00	-0.86833E+01	-0.52259E+05	0.49117E+01
	93.56	-0.70961E+00	-0.34827E+01	-0.17486E+04	0.13321E+02
14	168.91	0.20219E+00	-0.10149E+02	-0.67210E+05	0.57315E+01
	88.19	-0.66420E+00	-0.78963E+01	-0.19694E+04	0.19320E+02
15	171.76	0.24020E+00	-0.73138E+01	-0.58488E+05	0.47460E+01
	75.95	-0.65472E+00	-0.24821E+01	-0.21360E+04	0.12701E+02
16	173.47	0.26804E+00	-0.89214E+01	-0.48474E+05	0.37441E+01
	63.50	-0.65014E+00	-0.27527E+01	-0.21131E+04	0.92532E+01
17	174.00	0.27734E+00	-0.10049E+02	-0.37390E+05	0.33970E+01
	50.94	-0.64887E+00	-0.71962E+00	-0.20938E+04	0.80464E+01
18	174.00	0.25645E+00	-0.66145E+01	-0.23447E+05	0.34814E+01
	33.96	-0.64760E+00	0.15080E+01	-0.20849E+04	0.76023E+01
19	174.00	0.20852E+00	-0.21693E+01	-0.11411E+05	0.36437E+01
	16.98	-0.64649E+00	0.54479E+00	-0.20851E+04	0.65029E+01
20	174.00	0.14995E+00	0.22758E+01	0.70713E-10	0.61687E+01
	0.00	-0.64578E+00	-0.41845E+00	-0.20936E+04	0.00000E+00

SHEAR FORCE DIAGNOSTCS FOR CONCRETE-GROUP 1, LOAD STEP 13
-- V-factor is coefficient of sqrt(PFPC) equal to capacity.
-- Shear depth "d" is negative if measured from outer wall.
-- Stirrup load is excess shear force above capacity.

NODE	EQUIVALENT V-factor	SHEAR CAPACITY lbs/inch	APPLIED SHEAR lbs/inch	APPLIED/ CAPACITY ratio	SHEAR DEPTH-d inches	STIRRUP LOAD lbs/inch
1	2.75	1773.95	1.22	0.001	8.00	0.00
2	2.75	1774.38	13.62	0.008	8.00	0.00
3	2.75	1774.79	25.35	0.014	8.00	0.00
4	2.75	1774.82	49.68	0.028	8.00	0.00
5	2.75	1774.28	117.23	0.066	8.00	0.00
6	2.75	1774.79	234.75	0.132	8.00	0.00
7	2.74	1780.04	383.19	0.215	8.06	0.00
8	4.50	2923.16	557.58	0.191	8.06	0.00
9	4.50	2764.55	706.16	0.255	-7.63	0.00

10	3.70	2444.58	836.83	0.342	-8.19	0.00
11	2.46	1957.00	941.18	0.481	-9.88	0.00
12	1.94	1981.88	1002.22	0.506	-12.69	0.00
13	1.73	2325.18	1075.82	0.463	-16.69	0.00
14	1.43	2834.63	210.73	0.074	-24.56	0.00
15	1.69	2165.82	-745.50	0.344	-15.88	0.00
16	2.05	1836.29	-839.10	0.457	-11.13	0.00
17	2.26	1739.77	-851.39	0.489	-9.56	0.00
18	2.34	1803.29	-765.03	0.424	-9.56	0.00
19	3.85	2968.75	-690.46	0.233	-9.56	0.00
20	4.50	3625.40	-653.62	0.180	10.00	0.00

STRESS AND STRAIN MEASURES FOR CONCRETE-GROUP 1, LOAD STEP 13

NODE	MAXIMUM COMPRESSION psi	AVERAGE SHEAR psi	RADIAL TENSION psi	INNER-WALL STRAIN in/in	OUTER-WALL STRAIN in/in
1	-1833.35	0.16	6.53	0.6235E-03	-0.3874E-03
2	-1826.30	1.75	6.49	0.6200E-03	-0.3859E-03
3	-1804.42	3.26	6.42	0.6105E-03	-0.3813E-03
4	-1769.47	6.38	6.25	0.5959E-03	-0.3739E-03
5	-1695.31	15.07	5.86	0.5598E-03	-0.3582E-03
6	-1507.65	30.17	5.04	0.4847E-03	-0.3186E-03
7	-1113.76	48.85	3.31	0.3244E-03	-0.2354E-03
8	-530.21	71.08	0.78	0.8998E-04	-0.1120E-03
9	-530.21	90.02	0.00	-0.1076E-03	0.8998E-04
10	-1369.43	99.55	0.00	-0.2894E-03	0.5118E-03
11	-1805.56	93.24	0.00	-0.3815E-03	0.7801E-03
12	-1785.16	77.65	0.00	-0.3772E-03	0.8397E-03
13	-1574.79	63.63	0.00	-0.3328E-03	0.7967E-03
14	-1134.56	8.50	0.00	-0.2398E-03	0.6383E-03
15	-1916.12	-46.32	0.00	-0.4049E-03	0.9490E-03
16	-2747.23	-73.97	0.00	-0.5805E-03	0.1278E-02
17	-2750.84	-87.04	0.00	-0.5813E-03	0.1213E-02
18	-1927.37	-78.21	0.00	-0.4073E-03	0.7314E-03
19	-1052.27	-70.59	0.00	-0.2224E-03	0.2849E-03
20	-156.86	-66.82	0.00	-0.3315E-04	-0.3315E-04

STEEL STRESS AND CRACK WIDTHS FOR CONCRETE-GROUP 1, LOAD STEP 13
NOTE: CRACK WIDTH IS REDUCED TO SERVICE-LOAD LEVEL.
ALL OTHER RESPONSES ARE AT FACTORED LOAD LEVEL.

NODE	INNER CAGE psi	OUTER CAGE psi	MAX STRESS TO YIELD ratio	CRACK WIDTH inches
1	13427.81	-4493.19	0.2238	0.00012
2	13345.67	-4485.22	0.2224	0.00009
3	13134.29	-4447.19	0.2189	0.00001
4	12808.55	-4382.77	0.2135	0.00000
5	11988.94	-4285.27	0.1998	0.00000
6	10326.99	-3912.91	0.1721	0.00000
7	6793.64	-3179.17	0.1132	0.00000
8	1587.96	-2011.09	0.0335	0.00000
9	-2178.11	1342.27	0.0363	0.00000
10	-4415.76	10453.83	0.1742	0.00000
11	-6146.01	17532.06	0.2922	0.00000

12	-6893.45	20510.83	0.3418	0.00000
13	-6840.82	20802.64	0.3467	0.00000
14	-5567.80	17814.05	0.2969	0.00000
15	-8191.37	24501.14	0.4084	0.00000
16	-9767.32	30080.09	0.5013	0.00292
17	-8992.50	27051.72	0.4509	0.00251
18	-6931.66	15936.41	0.2656	0.00000
19	-4392.12	5795.12	0.0966	0.00000
20	-1056.32	-1056.32	0.0176	0.00000

ASSESSMENT SUMMARY CONCRETE-GROUP 1, LOAD-STEP 13

LRFD SUMMARY EVALUATION FOR GROUP 1, LOAD STEP 13

DESIGN-CRITERION	CONTROL NODE	FACTORED DEMAND	FACTORED CAPACITY	RATIO VALUE
STEEL YIELDING (psi)	16	30080.1	60000.0	0.501
CONCRETE CRUSHING (psi)	17	2750.8	4875.0	0.564
SHEAR FAILURE (lbs/in)	12	1002.2	1783.7	0.562
RADIAL-TENSION FAIL (psi)	1	6.5	69.6	0.094

LRFD SERVICE-LOAD PERFORMANCE MEASURES FOR GROUP 1, LOAD STEP 13

NODE NUMBER FOR MAXIMUM CRACK WIDTH 16

MAXIMUM CRACK WIDTH AT SERVICE LOAD (inches) 0.00292

LRFD RATIO: MAX-CRACK-WIDTH / ALLOWABLE 0.29

SPAN LENGTH FOR AUXILIARY EQUATIONS (inches)..... 348.00

* * * * NORMAL EXIT FROM CANDE * * * *

28x10_6Axlec1Mod.out

```
*** WELCOME TO CANDE-2013(version 3/1/2013) ***

MASTER CONTROL AND PIPE-TYPE DATA FOR PROBLEM #  1

        USER TITLE: 28x10

        EXECUTION MODE ..................   ANALYS

        SOLUTION LEVEL ..................  #2 AUTO

        METHODOLOGY (LRFD OR SERVICE) ...     LRFD

        NUMBER OF PIPE-ELEMENT GROUPS ....       1

        MAXIMUM ITERATIONS PER STEP ......      30


        CULVERT PIPE-TYPE ............... CONCRETE

        CANNED MESH CODE # ..............        3

        NUMBER OF BEAM ELEMENTS .........       19

        CONCRETE MATERIAL PROPERTIES ARE AS FOLLOWS

             COMPRESSION STRENGTH (psi)..........       6500.000

             ELASTIC YOUNGS MODULUS (psi)........    4595487.000

             POISSON RATIO ......................          0.170

             CONCRETE DENSITY (pcf) .............        150.000

             INITIAL TENSILE CRACKING STRAIN.....       0.000010

             INITIAL COMPRESSION YIELD STRAIN....       0.000687

             INITIAL COMPRESSION CRUSH STRAIN ...       0.002000

             SHEAR STRENGTH MODEL (NSHEAR) # ...          1
             (VARIABLE STRENGTH MODEL PRINTED IN OUTPUT)

             CONCRETE CRACK-WIDTH MODEL NAME.....   HEGER-McGRATH
             (DRIVEN BY TENSILE STRAIN IN STEEL)

        STEEL REINFORCEMENT MATERIAL PROPERTIES

             TYPE OF STEEL CAGES (RSHAPE) .......     ARBIT

             STEEL YIELD STRENGTH (psi)..........      60000.000

             STEEL ELASTIC MODULUS (psi).........   29000000.000
```

28x10_6Axlec1Mod.out

STEEL POISSON RATIO 0.300000

STEEL YIELDING STRAIN 0.001883

NONLINEAR MODELING CODE (1,2,3) 3

STEEL-BASED CRACKWIDTH PREDICTION PARAMETERS

REBAR SPACING INNER ROW (SLI), (in)	4.00
REBAR SPACING OUTER ROW (SLO), (in)	4.00
NUMBER OF STEEL LAYERS FOR INNER CAGE	1
NUMBER OF STEEL LAYERS FOR OUTER CAGE	1
HEGER-MCGRATH CODE NUMBER FOR STEEL TYPE..	3

WALL THICKNESS, REBAR AREAS AND COVER DEPTHS

WALL-THICK	INNER-REBAR	OUTER-REBAR	INNER-COVER	OUTER COVER
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1100	0.1500	2.0000	2.4375
10.6250	0.1100	0.1500	2.0000	2.4375
12.3130	0.1100	0.1500	2.0000	2.4375
15.1250	0.1100	0.1500	2.0000	2.4375
19.1250	0.1100	0.1500	2.0000	2.4375
27.0000	0.1100	0.1500	2.0000	2.4375
18.3130	0.1100	0.1500	2.0000	2.4375
13.5630	0.1100	0.1500	2.0000	2.4375
12.0000	0.1100	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375

LRFD RESISTANCE FACTORS FOR STRENGTH-LIMIT STATES
AND CRACK-WIDTH LIMIT AT SERVICE LOAD

YIELDING OF REINFORCEMENT STEEL	1.000
CRUSHING OF CONCRETE OUTER FIBER.....	0.750
SHEARING FAILURE OF CONCRETE	0.900
SPLITTING OF CONCRETE IN RADIAL TENSION	0.900
ALLOWABLE CRACKWIDTH SERVICE LOAD (inch)....	0.010

LARGE DEFORMATION/BUCKLING CODE, IBUCK = 0
IBUCK=0, MEANS SMALL DEFORMATION THEORY FOR GROUP
AND NO BUCKLING PREDICTION.

28x10_6Axlec1Mod.out

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


 REVIEW SYSTEM INPUT DATA


 LEVEL-2 DATA FOR ARCH-TYPE CANNED MESH


    *** MESH PARAMETERS ***
     TYPE OF MESH ------------------------------------- TREN
     DEPTH OF TRENCH ABOVE FOOTING LEVEL (FT) ---------   12.42
     WIDTH OF TRENCH AT FOOTING LEVEL (FT) ------------    5.00
     SLOPE OF TRENCH WALL (H/V) -----------------------    0.00
     MESH SPACING PARAMETER ---------------------------    1.00
     TOTAL SOIL HEIGHT ABOVE CROWN (FT) ---------------    2.00
     MESH HEIGHT ABOVE CROWN (FT) ----------------------    2.00
     SOIL DENSITY ABOVE MESH (PCF) ---------------------  140.00
     NUMBER OF ELEMENT LAYERS ABOVE CROWN -------------    3


*** ARCH PARAMETERS ***
     CENTERLINE RISE OF ARCH (IN) ----------------------  125.00
     BOTTOM HALF SPAN OF ARCH (IN) ---------------------  174.00
     SIDE RISE OF ARCH ABOVE FOOTING (IN) -------------   50.94
     FOOTING DEPTH (IN) --------------------------------   24.00
     OUTSIDE FOOTING WIDTH (IN) ------------------------   30.00
     INSIDE FOOTING WIDTH (IN) -------------------------   30.00
     NUMBER OF ARCH SEGMENTS DEFINED -------------------    3

*** CURVED TOP SEGMENT ***
     RADIUS (IN) ---------------------------------------  405.88
     CENTRAL ANGLE (DEG) -------------------------------   24.59
     SEGMENT ARC LENGTH (IN) ---------------------------  174.19
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------   13

*** CURVED CORNER SEGMENT ***
     RADIUS (IN) ---------------------------------------  133.94
     CENTRAL ANGLE (DEG) -------------------------------   16.14
     SEGMENT ARC LENGTH (IN) ---------------------------   37.73
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

*** STRAIGHT SIDE SEGMENT ***
     DEFLECTION ANGLE (DEG) ----------------------------   90.00
     SEGMENT LENGTH (IN) -------------------------------   50.94
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

 FINITE ELEMENT INPUT CONTROLS (PREP)


THE DATA TO BE RUN IS ENTITLED ...

New Level 2 arch mesh

PRINT AND PLOT CONTROL CODES ...
  PRINT CONTROL FOR MESH DATA------------    1
  PLOT FILE CONTROL MESH & RESULS--------    3
  PRINT FINITE ELEMENT RESULTS ----------    1
  INPUT DATA CHECK CODE------------------    0
```

28x10_6Axlec1Mod.out

```
KEY NUMBERS DESCRIBING MESH ...
  THE NUMBER OF LOAD STEPS IS------------   13
  TOTAL NUMBER OF NODES IS---------------  244
  TOTAL NUMBER OF ELEMENTS IS------------  209
  TOTAL NUMBER OF BEAM ELEMENTS IS-------   19
  MAX NUMBER OF BOUNDARY CONDITIONS IS---   36


 EXTENDED LEVEL-2: CHANGES TO CANNED MESH

          * NUMBER OF NODES TO BE CHANGED -------      0 *
          * NUMBER OF ELEMENTS TO BE CHANGED ----      0 *
          * ADDITIONAL BOUNDARY CONDITIONS ------     31 *


 * * * BOUNDARY CONDITIONS * * *
  (FORCES = LBS; DISPLACEMENTS = INCHES; ROTATIONS = DEGREES)

  BOUNDARY      LOAD      X-FORCE     OR      Y-FORCE     OR      X-Y ROTATION
BEAM ROTATIONAL
     NODE       STEP      X-DISPLACEMENT      Y-DISPLACEMENT
BOUNDARY CONDITIONS

      224        10    F =   0.0000E+00    F =  -0.5579E+02      0.0000E+00
     F
      224        11    F =   0.0000E+00    F =  -0.5579E+02      0.0000E+00
     F
      224        12    F =   0.0000E+00    F =  -0.5579E+02      0.0000E+00
     F
      224        13    F =   0.0000E+00    F =  -0.5579E+02      0.0000E+00
     F
      227        10    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      227        11    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      227        12    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      227        13    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      224        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      225        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      226        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      227        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      228        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
```

```
F
 231        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 232        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 233        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 224         9    F =   0.0000E+00    F =  -0.2188E+01      0.0000E+00
F
 225         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 226         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 227         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 228         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 229         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 230         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 231         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 232         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 233         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 234         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 235         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 236         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F

* * * * * COMPLETED MESH GENERATION  * * * * *

New Level 2 arch mesh

CALCULATED KEY NUMBERS ...
  THE NUMBER OF DATA ERRORS IS-----------    0
  THE NUMBER OF SOIL MATERIALS IS--------    3
  THE NUMBER OF PIPE-TYPE GROUPS IS------    1
  THE NUMBER OF INTERFACE MATERIALS IS---   19
  BAND WIDTH ESTIMATE (MAX)--------------   88


* * * * MESH DATA HAS BEEN SAVED ON UNIT 14 * * * *


 BEAM-NODE SEQUENCE NUMBERS FOR EACH GROUP


    BEAM-ELEMENT GROUP NUMBER =    1

     BEAM-NODE       MESH-NODE      CONNECTED-GROUP-ELEMENTS
     SEQUENCE        NUMBER         FOREWARD-#     BACKWARD-#
         1             198              1              0
         2             194              2              1
         3             190              3              2
         4             167              4              3
```

5	164	5	4
6	161	6	5
7	158	7	6
8	138	8	7
9	136	9	8
10	134	10	9
11	132	11	10
12	130	12	11
13	128	13	12
14	118	14	13
15	115	15	14
16	109	16	15
17	103	17	16
18	97	18	17
19	91	19	18
20	80	0	19

```
MATERIAL DESCRIPTION FOR SOILS AND INTERFACE
(ALL DENSITY UNITS ARE pcf, ALL MODULUS UNITS ARE psi)

   PROPERTIES FOR MATERIAL  1   ********in site

        DENSITY =    0.14000E+03

        YOUNGS MODULUS= 0.5000E+04
        POISSONS RATIO= 0.3500E+00
        CONFINED MOD.= 0.8025E+04
        LATERAL COEFF.= 0.5385E+00

   PROPERTIES FOR MATERIAL  2   ********Footing

        DENSITY =    0.15000E+03

        YOUNGS MODULUS= 0.3122E+07
        POISSONS RATIO= 0.1700E+00
        CONFINED MOD.= 0.3356E+07
        LATERAL COEFF.= 0.2048E+00

   PROPERTIES FOR MATERIAL  3   ********SW95

        DENSITY =    0.14000E+03

   CONTROLS FOR DUNCAN SOIL MODEL
   WITH SELIG HYPERBOLIC BULK MODULUS FORMULATION

         LRFD STRESS CONTROL..........       0

         ENTERING ELEMENT RATIO.......      0.5000


   HYPERBOLIC STRESS-STRAIN PARAMETERS


         SOIL CLASSIFICATION ............SW95
```

COHESION INTERCEPT C 0.0000

FRICTION ANGLE PHIO (DEG)..... 48.0000

10-FOLD REDUCTION IN PHIO(DEG).. 8.0000

SCALED MODULUS NUMBER ZK 950.0000

MODULUS EXPONENT ZN 0.6000

FAILURE RATIO RF 0.7000

INIT. BULK MODULUS NUMBER BI.... 74.8000

ULT. VOLUMETRIC STRAIN EU 0.0200

INTERFACE ELEMENT MATERIAL-GROUP PROPERTIES

MAT. NO.	NORMAL-ANGLE	COEF-FRICTION	TENSILE-RUPTURE	INITIAL-GAP
1	90.00	0.40000	10.00000	0.00000
2	88.11	0.40000	10.00000	0.00000
3	86.22	0.40000	10.00000	0.00000
4	84.32	0.40000	10.00000	0.00000
5	82.43	0.40000	10.00000	0.00000
6	80.54	0.40000	10.00000	0.00000
7	78.65	0.40000	10.00000	0.00000
8	76.76	0.40000	10.00000	0.00000
9	74.87	0.40000	10.00000	0.00000
10	72.97	0.40000	10.00000	0.00000
11	71.08	0.40000	10.00000	0.00000
12	69.19	0.40000	10.00000	0.00000
13	67.30	0.40000	10.00000	0.00000
14	65.41	0.40000	10.00000	0.00000
15	10.46	0.40000	10.00000	0.00000
16	5.11	0.40000	10.00000	0.00000
17	0.00	0.40000	10.00000	0.00000
18	0.00	0.40000	10.00000	0.00000
19	0.00	0.40000	10.00000	0.00000

LRFD TOTAL LOAD FACTORS PER LOAD STEP

LOAD STEP	LOAD FACTOR	USER COMMENT
1	1.310	Factor for load step #1
2	0.857	Factor for load step #2
3	0.857	Factor for load step #3
4	0.857	Factor for load step #4
5	1.365	Factor for load step #5
6	1.365	Factor for load step #6
7	1.365	Factor for load step #7

28x10_6Axle c1Mod.out

8	1.365	Factor for load step #8
9	1.500	Factor for load step #9
10	1.350	Factor for load step #10
11	1.350	Factor for load step #11
12	1.350	Factor for load step #12
13	1.350	Factor for load step #13

+ +

SOLUTION OUTPUT RESULTS

+ +

FINITE ELEMENT OUTPUT FOR LOAD STEP 13

+ +

CONCRETE, FACTORED-EVALUATION FOR GROUP 1, LOAD-STEP 13

STRUCTURAL RESPONSES OF CONCRETE-GROUP 1, LOAD-STEP 13
COORDINATES, DISPLACEMENTS AND CRACK DEPTHS ARE INCHES
Y-BAR IS "NEUTRAL AXIS" LOCATION FROM INTERIOR, INCHES
PRESSURES ARE LB/IN**2
MOMENTS ARE IN-LB/IN
THRUST AND SHEAR ARE LB/IN

LOCAL NODE	X-COORD. Y-COORD.	X-DISP. Y-DISP.	N-PRES. S-PRES.	MOMENT THRUST	Y-BAR CRACK DEPTH
1	0.00	0.00000E+00	-0.14068E+02	0.43556E+05	0.65367E+01
	125.00	-0.20478E+01	-0.69176E+01	-0.12991E+04	0.63293E+01
2	13.42	-0.34711E-03	-0.11947E+02	0.41962E+05	0.65514E+01
	124.78	-0.20280E+01	-0.46852E+01	-0.13683E+04	0.63090E+01
3	26.80	0.18129E-02	-0.98263E+01	0.38672E+05	0.65892E+01
	124.11	-0.19702E+01	-0.24528E+01	-0.14246E+04	0.62796E+01
4	40.15	0.87565E-02	-0.16674E+02	0.34094E+05	0.66148E+01
	123.01	-0.18776E+01	0.68210E+00	-0.14495E+04	0.62326E+01
5	53.46	0.22291E-01	-0.15424E+02	0.27007E+05	0.66148E+01
	121.47	-0.17549E+01	-0.58682E+01	-0.15029E+04	0.61120E+01
6	66.71	0.43426E-01	-0.13097E+02	0.17662E+05	0.65476E+01
	119.48	-0.16089E+01	-0.51719E+01	-0.16013E+04	0.58063E+01

7	79.89	0.72137E-01	-0.10039E+02	0.65198E+04	0.63124E+01
	117.06	-0.14489E+01	-0.39656E+01	-0.16917E+04	0.42694E+01
8	92.98	0.10721E+00	-0.21237E+01	-0.58323E+04	0.30403E+01
	114.21	-0.12855E+01	-0.80516E+00	-0.17557E+04	0.46662E+01
9	105.97	0.14636E+00	-0.44575E+01	-0.17940E+05	0.29481E+01
	110.92	-0.11282E+01	-0.17485E+01	-0.18058E+04	0.64416E+01
10	118.85	0.18544E+00	-0.53711E+01	-0.30202E+05	0.30809E+01
	107.21	-0.98927E+00	-0.21220E+01	-0.18655E+04	0.70750E+01
11	131.59	0.22032E+00	-0.64768E+01	-0.42766E+05	0.34674E+01
	103.08	-0.87874E+00	-0.25722E+01	-0.19322E+04	0.83650E+01
12	144.19	0.24977E+00	-0.74747E+01	-0.55824E+05	0.40809E+01
	98.53	-0.79478E+00	-0.29819E+01	-0.20073E+04	0.10454E+02
13	156.64	0.27448E+00	-0.93136E+01	-0.69562E+05	0.45666E+01
	93.56	-0.73079E+00	-0.36568E+01	-0.20936E+04	0.13506E+02
14	168.91	0.29607E+00	-0.11830E+02	-0.84332E+05	0.57315E+01
	88.19	-0.67972E+00	-0.54964E+01	-0.22317E+04	0.19560E+02
15	171.76	0.33777E+00	-0.97729E+01	-0.72453E+05	0.44372E+01
	75.95	-0.66929E+00	-0.24463E+01	-0.23032E+04	0.12863E+02
16	173.47	0.36677E+00	-0.11768E+02	-0.59471E+05	0.37633E+01
	63.50	-0.66448E+00	-0.25989E+01	-0.22573E+04	0.93278E+01
17	174.00	0.37290E+00	-0.12500E+02	-0.45700E+05	0.34106E+01
	50.94	-0.66328E+00	-0.95879E-01	-0.22176E+04	0.81221E+01
18	174.00	0.34024E+00	-0.81304E+01	-0.28654E+05	0.34814E+01
	33.96	-0.66195E+00	0.27614E+01	-0.21891E+04	0.77357E+01
19	174.00	0.27433E+00	-0.26111E+01	-0.13950E+05	0.36437E+01
	16.98	-0.66076E+00	0.72179E+00	-0.21772E+04	0.68190E+01
20	174.00	0.19525E+00	0.29083E+01	0.16530E-09	0.61687E+01
	0.00	-0.66001E+00	-0.13178E+01	-0.21827E+04	0.00000E+00

SHEAR FORCE DIAGNOSTCS FOR CONCRETE-GROUP 1, LOAD STEP 13
-- V-factor is coefficient of sqrt(PFPC) equal to capacity.
-- Shear depth "d" is negative if measured from outer wall.
-- Stirrup load is excess shear force above capacity.

NODE	EQUIVALENT V-factor	SHEAR CAPACITY lbs/inch	APPLIED SHEAR lbs/inch	APPLIED/ CAPACITY ratio	SHEAR DEPTH-d inches	STIRRUP LOAD lbs/inch
1	2.77	1784.24	55.40	0.031	8.00	0.00
2	2.78	1790.04	182.16	0.102	8.00	0.00
3	2.78	1794.76	293.62	0.164	8.00	0.00
4	2.79	1796.84	435.31	0.242	8.00	0.00
5	2.79	1801.31	613.17	0.340	8.00	0.00
6	3.10	1996.25	764.52	0.383	8.00	0.00
7	4.50	2923.16	876.72	0.300	8.06	0.00
8	4.50	2764.55	912.75	0.330	-7.63	0.00

9	3.22	1978.07	909.43	0.460	-7.63	0.00
10	2.50	1648.83	926.46	0.562	-8.19	0.00
11	2.19	1747.47	956.12	0.547	-9.88	0.00
12	1.89	1932.72	999.89	0.517	-12.69	0.00
13	1.65	2223.41	1063.85	0.478	-16.69	0.00
14	1.44	2847.92	78.28	0.027	-24.56	0.00
15	1.70	2175.16	-989.25	0.455	-15.88	0.00
16	2.06	1845.34	-1063.99	0.577	-11.13	0.00
17	2.27	1748.02	-1049.67	0.600	-9.56	0.00
18	2.32	1787.93	-934.96	0.523	-9.56	0.00
19	3.77	2908.81	-843.77	0.290	-9.56	0.00
20	4.50	3625.40	-799.43	0.221	10.00	0.00

STRESS AND STRAIN MEASURES FOR CONCRETE-GROUP 1, LOAD STEP 13

NODE	MAXIMUM COMPRESSION psi	AVERAGE SHEAR psi	RADIAL TENSION psi	INNER-WALL STRAIN in/in	OUTER-WALL STRAIN in/in
1	-3544.82	7.12	15.08	0.1417E-02	-0.8059E-03
2	-3479.08	23.41	14.45	0.1359E-02	-0.7793E-03
3	-3333.76	37.73	13.24	0.1243E-02	-0.7206E-03
4	-3032.17	55.94	11.52	0.1087E-02	-0.6407E-03
5	-2462.42	78.80	8.89	0.8437E-03	-0.5203E-03
6	-1710.02	98.25	5.39	0.5242E-03	-0.3614E-03
7	-724.46	111.77	1.15	0.1302E-03	-0.1531E-03
8	-604.89	116.36	0.00	-0.1278E-03	0.1292E-03
9	-2019.37	115.94	0.00	-0.4267E-03	0.7868E-03
10	-2860.29	110.21	0.00	-0.6044E-03	0.1235E-02
11	-2920.29	94.72	0.00	-0.6171E-03	0.1339E-02
12	-2539.38	77.47	0.00	-0.5366E-03	0.1233E-02
13	-2054.21	62.93	0.00	-0.4341E-03	0.1077E-02
14	-1397.20	3.16	0.00	-0.2953E-03	0.8125E-03
15	-2320.73	-61.47	0.00	-0.4904E-03	0.1191E-02
16	-3289.25	-93.79	0.00	-0.7026E-03	0.1580E-02
17	-3281.30	-107.31	0.00	-0.6994E-03	0.1496E-02
18	-2293.44	-95.59	0.00	-0.4846E-03	0.9073E-03
19	-1246.22	-86.26	0.00	-0.2633E-03	0.3698E-03
20	-163.53	-81.73	0.00	-0.3456E-04	-0.3456E-04

STEEL STRESS AND CRACK WIDTHS FOR CONCRETE-GROUP 1, LOAD STEP 13
NOTE: CRACK WIDTH IS REDUCED TO SERVICE-LOAD LEVEL.
ALL OTHER RESPONSES ARE AT FACTORED LOAD LEVEL.

NODE	INNER CAGE psi	OUTER CAGE psi	MAX STRESS TO YIELD ratio	CRACK WIDTH inches
1	30985.73	-8416.51	0.5164	0.00700
2	29684.83	-8224.25	0.4947	0.00649
3	27102.47	-7709.99	0.4517	0.00548
4	23617.59	-7001.84	0.3936	0.00412
5	18193.40	-5986.77	0.3032	0.00200
6	11059.82	-4637.23	0.1843	0.00000
7	2354.47	-2692.05	0.0449	0.00000
8	-2445.80	2132.47	0.0408	0.00000
9	-5912.65	15707.05	0.2618	0.00000
10	-8230.68	25897.05	0.4316	0.00283

11	-9542.04	30323.51	0.5054	0.00377
12	-9641.82	30217.28	0.5036	0.00218
13	-8796.54	28193.97	0.4699	0.00000
14	-6794.02	22707.07	0.3785	0.00000
15	-9775.97	30826.30	0.5138	0.00063
16	-11667.17	37266.48	0.6211	0.00593
17	-10629.36	33460.04	0.5577	0.00519
18	-8051.44	19903.97	0.3317	0.00000
19	-5029.66	7685.56	0.1281	0.00000
20	-1101.28	-1101.28	0.0184	0.00000

ASSESSMENT SUMMARY CONCRETE-GROUP 1, LOAD-STEP 13

LRFD SUMMARY EVALUATION FOR GROUP 1, LOAD STEP 13

DESIGN-CRITERION	CONTROL NODE	FACTORED DEMAND	FACTORED CAPACITY	RATIO VALUE
STEEL YIELDING (psi)	16	37266.5	60000.0	0.621
CONCRETE CRUSHING (psi)	1	3544.8	4875.0	0.727
SHEAR FAILURE (lbs/in)	17	1049.7	1573.2	0.667
RADIAL-TENSION FAIL (psi)	1	15.1	69.6	0.217

LRFD SERVICE-LOAD PERFORMANCE MEASURES FOR GROUP 1, LOAD STEP 13

NODE NUMBER FOR MAXIMUM CRACK WIDTH 1

MAXIMUM CRACK WIDTH AT SERVICE LOAD (inches) 0.00700

LRFD RATIO: MAX-CRACK-WIDTH / ALLOWABLE 0.70

SPAN LENGTH FOR AUXILIARY EQUATIONS (inches)..... 348.00

* * * * NORMAL EXIT FROM CANDE * * * *

28x10_6Axlec2Mod.out

```
*** WELCOME TO CANDE-2013(version 3/1/2013) ***

MASTER CONTROL AND PIPE-TYPE DATA FOR PROBLEM #  1

        USER TITLE: 28x10

        EXECUTION MODE ..................   ANALYS

        SOLUTION LEVEL ..................  #2 AUTO

        METHODOLOGY (LRFD OR SERVICE) ...     LRFD

        NUMBER OF PIPE-ELEMENT GROUPS ....       1

        MAXIMUM ITERATIONS PER STEP ......      30


        CULVERT PIPE-TYPE ............... CONCRETE

        CANNED MESH CODE # ..............        3

        NUMBER OF BEAM ELEMENTS .........       19

        CONCRETE MATERIAL PROPERTIES ARE AS FOLLOWS

             COMPRESSION STRENGTH (psi)..........       6500.000

             ELASTIC YOUNGS MODULUS (psi)........    4595487.000

             POISSON RATIO ......................          0.170

             CONCRETE DENSITY (pcf) .............        150.000

             INITIAL TENSILE CRACKING STRAIN.....       0.000010

             INITIAL COMPRESSION YIELD STRAIN....       0.000687

             INITIAL COMPRESSION CRUSH STRAIN ...       0.002000

             SHEAR STRENGTH MODEL (NSHEAR) # ...          1
             (VARIABLE STRENGTH MODEL PRINTED IN OUTPUT)

             CONCRETE CRACK-WIDTH MODEL NAME.....   HEGER-McGRATH
             (DRIVEN BY TENSILE STRAIN IN STEEL)

        STEEL REINFORCEMENT MATERIAL PROPERTIES

             TYPE OF STEEL CAGES (RSHAPE) .......     ARBIT

             STEEL YIELD STRENGTH (psi)..........      60000.000

             STEEL ELASTIC MODULUS (psi).........   29000000.000
```

28x10_6Axlec2Mod.out

STEEL POISSON RATIO 0.300000

STEEL YIELDING STRAIN 0.001883

NONLINEAR MODELING CODE (1,2,3) 3

STEEL-BASED CRACKWIDTH PREDICTION PARAMETERS
REBAR SPACING INNER ROW (SLI), (in) 4.00
REBAR SPACING OUTER ROW (SLO), (in) 4.00
NUMBER OF STEEL LAYERS FOR INNER CAGE 1
NUMBER OF STEEL LAYERS FOR OUTER CAGE 1
HEGER-MCGRATH CODE NUMBER FOR STEEL TYPE.. 3

WALL THICKNESS, REBAR AREAS AND COVER DEPTHS

WALL-THICK	INNER-REBAR	OUTER-REBAR	INNER-COVER	OUTER COVER
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1100	0.1500	2.0000	2.4375
10.6250	0.1100	0.1500	2.0000	2.4375
12.3130	0.1100	0.1500	2.0000	2.4375
15.1250	0.1100	0.1500	2.0000	2.4375
19.1250	0.1100	0.1500	2.0000	2.4375
27.0000	0.1100	0.1500	2.0000	2.4375
18.3130	0.1100	0.1500	2.0000	2.4375
13.5630	0.1100	0.1500	2.0000	2.4375
12.0000	0.1100	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375

LRFD RESISTANCE FACTORS FOR STRENGTH-LIMIT STATES
AND CRACK-WIDTH LIMIT AT SERVICE LOAD

YIELDING OF REINFORCEMENT STEEL 1.000

CRUSHING OF CONCRETE OUTER FIBER..... 0.750

SHEARING FAILURE OF CONCRETE 0.900

SPLITTING OF CONCRETE IN RADIAL TENSION 0.900

ALLOWABLE CRACKWIDTH SERVICE LOAD (inch).... 0.010

LARGE DEFORMATION/BUCKLING CODE, IBUCK = 0
IBUCK=0, MEANS SMALL DEFORMATION THEORY FOR GROUP
AND NO BUCKLING PREDICTION.

28x10_6Axlec2Mod.out

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


 REVIEW SYSTEM INPUT DATA


 LEVEL-2 DATA FOR ARCH-TYPE CANNED MESH


    *** MESH PARAMETERS ***
     TYPE OF MESH ------------------------------------- TREN
     DEPTH OF TRENCH ABOVE FOOTING LEVEL (FT) ---------   12.42
     WIDTH OF TRENCH AT FOOTING LEVEL (FT) ------------    5.00
     SLOPE OF TRENCH WALL (H/V) -----------------------    0.00
     MESH SPACING PARAMETER ---------------------------    1.00
     TOTAL SOIL HEIGHT ABOVE CROWN (FT) ---------------    2.00
     MESH HEIGHT ABOVE CROWN (FT) ----------------------    2.00
     SOIL DENSITY ABOVE MESH (PCF) --------------------  140.00
     NUMBER OF ELEMENT LAYERS ABOVE CROWN -------------    3


*** ARCH PARAMETERS ***
     CENTERLINE RISE OF ARCH (IN) ---------------------  125.00
     BOTTOM HALF SPAN OF ARCH (IN) --------------------  174.00
     SIDE RISE OF ARCH ABOVE FOOTING (IN) -------------   50.94
     FOOTING DEPTH (IN) -------------------------------   24.00
     OUTSIDE FOOTING WIDTH (IN) -----------------------   30.00
     INSIDE FOOTING WIDTH (IN) ------------------------   30.00
     NUMBER OF ARCH SEGMENTS DEFINED ------------------    3

*** CURVED TOP SEGMENT ***
     RADIUS (IN) --------------------------------------  405.88
     CENTRAL ANGLE (DEG) ------------------------------   24.59
     SEGMENT ARC LENGTH (IN) --------------------------  174.19
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------   13

*** CURVED CORNER SEGMENT ***
     RADIUS (IN) --------------------------------------  133.94
     CENTRAL ANGLE (DEG) ------------------------------   16.14
     SEGMENT ARC LENGTH (IN) --------------------------   37.73
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------    3

*** STRAIGHT SIDE SEGMENT ***
     DEFLECTION ANGLE (DEG) ---------------------------   90.00
     SEGMENT LENGTH (IN) ------------------------------   50.94
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------    3

 FINITE ELEMENT INPUT CONTROLS (PREP)


THE DATA TO BE RUN IS ENTITLED ...

New Level 2 arch mesh

PRINT AND PLOT CONTROL CODES ...
  PRINT CONTROL FOR MESH DATA------------    1
  PLOT FILE CONTROL MESH & RESULS--------    3
  PRINT FINITE ELEMENT RESULTS ----------    1
  INPUT DATA CHECK CODE------------------    0
```

28x10_6Axlec2Mod.out

```
KEY NUMBERS DESCRIBING MESH ...
  THE NUMBER OF LOAD STEPS IS------------   13
  TOTAL NUMBER OF NODES IS---------------  244
  TOTAL NUMBER OF ELEMENTS IS------------  209
  TOTAL NUMBER OF BEAM ELEMENTS IS-------   19
  MAX NUMBER OF BOUNDARY CONDITIONS IS---   36



 EXTENDED LEVEL-2: CHANGES TO CANNED MESH


          * NUMBER OF NODES TO BE CHANGED -------      0 *
          * NUMBER OF ELEMENTS TO BE CHANGED ----      0 *
          * ADDITIONAL BOUNDARY CONDITIONS ------     31 *



 * * * BOUNDARY CONDITIONS * * *
  (FORCES = LBS; DISPLACEMENTS = INCHES; ROTATIONS = DEGREES)

  BOUNDARY      LOAD      X-FORCE     OR      Y-FORCE     OR      X-Y ROTATION
BEAM ROTATIONAL
     NODE       STEP      X-DISPLACEMENT      Y-DISPLACEMENT
BOUNDARY CONDITIONS

      227        10    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      227        11    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      227        12    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      227        13    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      229        11    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      229        12    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      229        13    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      231        10    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      231        11    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      231        12    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      231        13    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      228        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
```

```
F
 231        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 232        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 233        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 224         9    F =   0.0000E+00    F =  -0.2188E+01      0.0000E+00
F
 225         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 226         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 227         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 228         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 229         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 230         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 231         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 232         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 233         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 234         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 235         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 236         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F

* * * * * COMPLETED MESH GENERATION  * * * * *

New Level 2 arch mesh

CALCULATED KEY NUMBERS ...
  THE NUMBER OF DATA ERRORS IS-----------     0
  THE NUMBER OF SOIL MATERIALS IS--------     3
  THE NUMBER OF PIPE-TYPE GROUPS IS------     1
  THE NUMBER OF INTERFACE MATERIALS IS---    19
  BAND WIDTH ESTIMATE (MAX)--------------    88


* * * * MESH DATA HAS BEEN SAVED ON UNIT 14 * * * *


 BEAM-NODE SEQUENCE NUMBERS FOR EACH GROUP


    BEAM-ELEMENT GROUP NUMBER =     1

     BEAM-NODE       MESH-NODE      CONNECTED-GROUP-ELEMENTS
     SEQUENCE        NUMBER         FOREWARD-#     BACKWARD-#
         1             198              1              0
         2             194              2              1
         3             190              3              2
         4             167              4              3
```

5	164	5	4
6	161	6	5
7	158	7	6
8	138	8	7
9	136	9	8
10	134	10	9
11	132	11	10
12	130	12	11
13	128	13	12
14	118	14	13
15	115	15	14
16	109	16	15
17	103	17	16
18	97	18	17
19	91	19	18
20	80	0	19

```
MATERIAL DESCRIPTION FOR SOILS AND INTERFACE
(ALL DENSITY UNITS ARE pcf, ALL MODULUS UNITS ARE psi)

   PROPERTIES FOR MATERIAL  1   ********in site

        DENSITY =    0.14000E+03

        YOUNGS MODULUS= 0.5000E+04
        POISSONS RATIO= 0.3500E+00
        CONFINED MOD.= 0.8025E+04
        LATERAL COEFF.= 0.5385E+00

   PROPERTIES FOR MATERIAL  2   ********Footing

        DENSITY =    0.15000E+03

        YOUNGS MODULUS= 0.3122E+07
        POISSONS RATIO= 0.1700E+00
        CONFINED MOD.= 0.3356E+07
        LATERAL COEFF.= 0.2048E+00

   PROPERTIES FOR MATERIAL  3   ********SW95

        DENSITY =    0.14000E+03

   CONTROLS FOR DUNCAN SOIL MODEL
   WITH SELIG HYPERBOLIC BULK MODULUS FORMULATION

         LRFD STRESS CONTROL..........       0

         ENTERING ELEMENT RATIO.......      0.5000


   HYPERBOLIC STRESS-STRAIN PARAMETERS


         SOIL CLASSIFICATION ............SW95
```

COHESION INTERCEPT C 0.0000

FRICTION ANGLE PHIO (DEG)..... 48.0000

10-FOLD REDUCTION IN PHIO(DEG).. 8.0000

SCALED MODULUS NUMBER ZK 950.0000

MODULUS EXPONENT ZN 0.6000

FAILURE RATIO RF 0.7000

INIT. BULK MODULUS NUMBER BI.... 74.8000

ULT. VOLUMETRIC STRAIN EU 0.0200

INTERFACE ELEMENT MATERIAL-GROUP PROPERTIES

MAT. NO.	NORMAL-ANGLE	COEF-FRICTION	TENSILE-RUPTURE	INITIAL-GAP
1	90.00	0.40000	10.00000	0.00000
2	88.11	0.40000	10.00000	0.00000
3	86.22	0.40000	10.00000	0.00000
4	84.32	0.40000	10.00000	0.00000
5	82.43	0.40000	10.00000	0.00000
6	80.54	0.40000	10.00000	0.00000
7	78.65	0.40000	10.00000	0.00000
8	76.76	0.40000	10.00000	0.00000
9	74.87	0.40000	10.00000	0.00000
10	72.97	0.40000	10.00000	0.00000
11	71.08	0.40000	10.00000	0.00000
12	69.19	0.40000	10.00000	0.00000
13	67.30	0.40000	10.00000	0.00000
14	65.41	0.40000	10.00000	0.00000
15	10.46	0.40000	10.00000	0.00000
16	5.11	0.40000	10.00000	0.00000
17	0.00	0.40000	10.00000	0.00000
18	0.00	0.40000	10.00000	0.00000
19	0.00	0.40000	10.00000	0.00000

LRFD TOTAL LOAD FACTORS PER LOAD STEP

LOAD STEP	LOAD FACTOR	USER COMMENT
1	1.310	Factor for load step #1
2	0.857	Factor for load step #2
3	0.857	Factor for load step #3
4	0.857	Factor for load step #4
5	1.365	Factor for load step #5
6	1.365	Factor for load step #6
7	1.365	Factor for load step #7

28x10_6Axlec2Mod.out

8	1.365	Factor for load step #8
9	1.500	Factor for load step #9
10	1.350	Factor for load step #10
11	1.350	Factor for load step #11
12	1.350	Factor for load step #12
13	1.350	Factor for load step #13

+ +

SOLUTION OUTPUT RESULTS

+ +

FINITE ELEMENT OUTPUT FOR LOAD STEP 13

+ +

CONCRETE, FACTORED-EVALUATION FOR GROUP 1, LOAD-STEP 13

STRUCTURAL RESPONSES OF CONCRETE-GROUP 1, LOAD-STEP 13
COORDINATES, DISPLACEMENTS AND CRACK DEPTHS ARE INCHES
Y-BAR IS "NEUTRAL AXIS" LOCATION FROM INTERIOR, INCHES
PRESSURES ARE LB/IN**2
MOMENTS ARE IN-LB/IN
THRUST AND SHEAR ARE LB/IN

LOCAL NODE	X-COORD. Y-COORD.	X-DISP. Y-DISP.	N-PRES. S-PRES.	MOMENT THRUST	Y-BAR CRACK DEPTH
1	0.00	0.00000E+00	0.11252E+01	0.32805E+05	0.66148E+01
	125.00	-0.22519E+01	-0.10821E+01	-0.18502E+04	0.61252E+01
2	13.42	-0.69126E-03	-0.29535E+01	0.32908E+05	0.66148E+01
	124.78	-0.22369E+01	0.69371E+00	-0.18408E+04	0.61287E+01
3	26.80	0.60511E-03	-0.70321E+01	0.33137E+05	0.66148E+01
	124.11	-0.21920E+01	0.24695E+01	-0.18201E+04	0.61370E+01
4	40.15	0.58835E-02	-0.14717E+02	0.32754E+05	0.66148E+01
	123.01	-0.21173E+01	0.27849E+01	-0.17877E+04	0.61377E+01
5	53.46	0.17053E-01	-0.16604E+02	0.30364E+05	0.66148E+01
	121.47	-0.20135E+01	-0.15816E+01	-0.17870E+04	0.60957E+01
6	66.71	0.35689E-01	-0.18837E+02	0.25630E+05	0.65476E+01
	119.48	-0.18834E+01	-0.41197E+01	-0.18389E+04	0.59738E+01

7	79.89	0.62644E-01	-0.22376E+02	0.18173E+05	0.65930E+01
	117.06	-0.17322E+01	-0.85409E+01	-0.19445E+04	0.57080E+01
8	92.98	0.97605E-01	-0.15577E+02	0.74031E+04	0.61238E+01
	114.21	-0.15687E+01	-0.25769E+01	-0.20472E+04	0.36063E+01
9	105.97	0.13910E+00	-0.26509E+02	-0.54094E+04	0.34272E+01
	110.92	-0.14017E+01	-0.10557E+02	-0.21709E+04	0.48605E+01
10	118.85	0.18398E+00	-0.12831E+02	-0.22174E+05	0.30809E+01
	107.21	-0.12421E+01	-0.36605E+01	-0.23093E+04	0.67718E+01
11	131.59	0.22774E+00	-0.21882E+02	-0.40383E+05	0.34674E+01
	103.08	-0.11035E+01	-0.87246E+01	-0.24424E+04	0.82199E+01
12	144.19	0.26752E+00	-0.10237E+02	-0.61627E+05	0.40809E+01
	98.53	-0.99022E+00	-0.40843E+01	-0.25849E+04	0.10378E+02
13	156.64	0.30286E+00	-0.10701E+02	-0.83792E+05	0.45666E+01
	93.56	-0.89901E+00	-0.42877E+01	-0.27033E+04	0.13458E+02
14	168.91	0.33497E+00	-0.11161E+02	-0.10697E+06	0.57315E+01
	88.19	-0.82342E+00	-0.99073E+01	-0.30054E+04	0.19530E+02
15	171.76	0.39866E+00	-0.10563E+02	-0.93091E+05	0.47460E+01
	75.95	-0.80758E+00	-0.25418E+01	-0.32177E+04	0.12791E+02
16	173.47	0.44616E+00	-0.13595E+02	-0.77170E+05	0.38703E+01
	63.50	-0.79992E+00	-0.26643E+01	-0.31512E+04	0.92805E+01
17	174.00	0.46389E+00	-0.14573E+02	-0.59692E+05	0.35078E+01
	50.94	-0.79785E+00	-0.34176E-01	-0.30927E+04	0.80810E+01
18	174.00	0.43400E+00	-0.10128E+02	-0.37531E+05	0.34814E+01
	33.96	-0.79598E+00	0.31263E+01	-0.30544E+04	0.77100E+01
19	174.00	0.36032E+00	-0.33038E+01	-0.18289E+05	0.36437E+01
	16.98	-0.79429E+00	0.99899E+00	-0.30370E+04	0.67970E+01
20	174.00	0.26926E+00	0.35199E+01	0.37630E-09	0.61687E+01
	0.00	-0.79323E+00	-0.11283E+01	-0.30378E+04	0.00000E+00

SHEAR FORCE DIAGNOSTCS FOR CONCRETE-GROUP 1, LOAD STEP 13
-- V-factor is coefficient of sqrt(PFPC) equal to capacity.
-- Shear depth "d" is negative if measured from outer wall.
-- Stirrup load is excess shear force above capacity.

NODE	EQUIVALENT V-factor	SHEAR CAPACITY lbs/inch	APPLIED SHEAR lbs/inch	APPLIED/ CAPACITY ratio	SHEAR DEPTH-d inches	STIRRUP LOAD lbs/inch
1	2.84	1830.40	-2.95	0.002	8.00	0.00
2	2.84	1829.62	-12.38	0.007	8.00	0.00
3	2.83	1827.89	5.73	0.003	8.00	0.00
4	2.83	1825.17	103.46	0.057	8.00	0.00
5	2.83	1825.12	265.84	0.146	8.00	0.00
6	2.84	1829.46	454.94	0.249	8.00	0.00
7	2.86	1859.04	680.17	0.366	8.06	0.00
8	4.50	2923.16	880.02	0.301	8.06	0.00
9	4.50	2764.55	1103.74	0.399	-7.63	0.00

10	3.62	2390.77	1305.15	0.546	-8.19	0.00
11	2.50	1994.00	1472.26	0.738	-9.88	0.00
12	2.00	2046.41	1619.80	0.792	-12.69	0.00
13	1.74	2344.35	1691.96	0.722	-16.69	0.00
14	1.46	2887.10	312.46	0.108	-24.56	0.00
15	1.74	2226.26	-1185.64	0.533	-15.88	0.00
16	2.12	1901.48	-1328.32	0.699	-11.13	0.00
17	2.34	1806.37	-1347.71	0.746	-9.56	0.00
18	2.40	1850.14	-1219.21	0.659	-9.56	0.00
19	3.93	3029.32	-1105.18	0.365	-9.56	0.00
20	4.50	3625.40	-1049.09	0.289	10.00	0.00

STRESS AND STRAIN MEASURES FOR CONCRETE-GROUP 1, LOAD STEP 13

NODE	MAXIMUM COMPRESSION psi	AVERAGE SHEAR psi	RADIAL TENSION psi	INNER-WALL STRAIN in/in	OUTER-WALL STRAIN in/in
1	-3001.67	-0.38	10.79	0.1029E-02	-0.6343E-03
2	-3008.41	-1.59	10.84	0.1032E-02	-0.6357E-03
3	-3021.99	0.74	10.97	0.1040E-02	-0.6386E-03
4	-2985.62	13.30	10.82	0.1028E-02	-0.6309E-03
5	-2787.14	34.16	9.94	0.9452E-03	-0.5890E-03
6	-2405.72	58.47	8.10	0.7791E-03	-0.5084E-03
7	-1738.75	86.71	5.14	0.5047E-03	-0.3674E-03
8	-710.54	112.19	0.78	0.9945E-04	-0.1501E-03
9	-866.26	140.71	0.00	-0.1831E-03	0.1710E-03
10	-2269.68	155.26	0.00	-0.4796E-03	0.8705E-03
11	-2857.94	145.85	0.00	-0.6039E-03	0.1243E-02
12	-2854.68	125.51	0.00	-0.6032E-03	0.1351E-02
13	-2500.87	100.08	0.00	-0.5285E-03	0.1289E-02
14	-1796.44	12.61	0.00	-0.3796E-03	0.1029E-02
15	-3027.94	-73.67	0.00	-0.6399E-03	0.1515E-02
16	-3863.25	-117.09	0.00	-0.9346E-03	0.2057E-02
17	-3868.16	-137.78	0.00	-0.9366E-03	0.1962E-02
18	-3038.32	-124.65	0.00	-0.6420E-03	0.1182E-02
19	-1674.96	-112.99	0.00	-0.3539E-03	0.4854E-03
20	-227.60	-107.25	0.00	-0.4810E-04	-0.4810E-04

STEEL STRESS AND CRACK WIDTHS FOR CONCRETE-GROUP 1, LOAD STEP 13
NOTE: CRACK WIDTH IS REDUCED TO SERVICE-LOAD LEVEL.
ALL OTHER RESPONSES ARE AT FACTORED LOAD LEVEL.

NODE	INNER CAGE psi	OUTER CAGE psi	MAX STRESS TO YIELD ratio	CRACK WIDTH inches
1	22178.34	-7297.56	0.3696	0.00355
2	22265.06	-7302.71	0.3711	0.00358
3	22454.49	-7308.57	0.3742	0.00366
4	22199.19	-7216.09	0.3700	0.00357
5	20342.30	-6852.47	0.3390	0.00284
6	16623.00	-6199.74	0.2771	0.00139
7	10559.69	-4977.15	0.1760	0.00000
8	1588.41	-2858.24	0.0476	0.00000
9	-3590.96	2716.97	0.0598	0.00000
10	-7185.78	17869.92	0.2978	0.00000
11	-9686.27	27957.90	0.4660	0.00278

12	-10989.76	33012.72	0.5502	0.00335
13	-10784.94	33692.83	0.5615	0.00140
14	-8773.40	28728.84	0.4788	0.00000
15	-12890.82	39143.03	0.6524	0.00411
16	-15725.21	48417.47	0.8070	0.01060
17	-14452.05	43757.54	0.7293	0.00950
18	-10773.49	25856.63	0.4309	0.00204
19	-6821.32	10036.61	0.1673	0.00000
20	-1532.73	-1532.73	0.0255	0.00000

ASSESSMENT SUMMARY CONCRETE-GROUP 1, LOAD-STEP 13

LRFD SUMMARY EVALUATION FOR GROUP 1, LOAD STEP 13

DESIGN-CRITERION	CONTROL NODE	FACTORED DEMAND	FACTORED CAPACITY	RATIO VALUE
STEEL YIELDING (psi)	16	48417.5	60000.0	0.807
CONCRETE CRUSHING (psi)	17	3868.2	4875.0	0.793
SHEAR FAILURE (lbs/in)	12	1619.8	1841.8	0.879
RADIAL-TENSION FAIL (psi)	3	11.0	69.6	0.158

LRFD SERVICE-LOAD PERFORMANCE MEASURES FOR GROUP 1, LOAD STEP 13

NODE NUMBER FOR MAXIMUM CRACK WIDTH 16

MAXIMUM CRACK WIDTH AT SERVICE LOAD (inches) 0.01060

LRFD RATIO: MAX-CRACK-WIDTH / ALLOWABLE 1.06

SPAN LENGTH FOR AUXILIARY EQUATIONS (inches)..... 348.00

* * * * NORMAL EXIT FROM CANDE * * * *

28x10_3Axlec1Mod.out

```
*** WELCOME TO CANDE-2013(version 3/1/2013) ***

MASTER CONTROL AND PIPE-TYPE DATA FOR PROBLEM #  1

        USER TITLE: 28x10

        EXECUTION MODE ..................   ANALYS

        SOLUTION LEVEL ..................  #2 AUTO

        METHODOLOGY (LRFD OR SERVICE) ...     LRFD

        NUMBER OF PIPE-ELEMENT GROUPS ....       1

        MAXIMUM ITERATIONS PER STEP ......      30


        CULVERT PIPE-TYPE ............... CONCRETE

        CANNED MESH CODE # ..............        3

        NUMBER OF BEAM ELEMENTS .........       19

        CONCRETE MATERIAL PROPERTIES ARE AS FOLLOWS

             COMPRESSION STRENGTH (psi)..........       6500.000

             ELASTIC YOUNGS MODULUS (psi)........    4595487.000

             POISSON RATIO ......................          0.170

             CONCRETE DENSITY (pcf) .............        150.000

             INITIAL TENSILE CRACKING STRAIN.....       0.000010

             INITIAL COMPRESSION YIELD STRAIN....       0.000687

             INITIAL COMPRESSION CRUSH STRAIN ...       0.002000

             SHEAR STRENGTH MODEL (NSHEAR) # ...          1
             (VARIABLE STRENGTH MODEL PRINTED IN OUTPUT)

             CONCRETE CRACK-WIDTH MODEL NAME.....   HEGER-McGRATH
             (DRIVEN BY TENSILE STRAIN IN STEEL)

        STEEL REINFORCEMENT MATERIAL PROPERTIES

             TYPE OF STEEL CAGES (RSHAPE) .......     ARBIT

             STEEL YIELD STRENGTH (psi)..........      60000.000

             STEEL ELASTIC MODULUS (psi).........   29000000.000
```

28x10_3Axlec1Mod.out

STEEL POISSON RATIO 0.300000

STEEL YIELDING STRAIN 0.001883

NONLINEAR MODELING CODE (1,2,3) 3

STEEL-BASED CRACKWIDTH PREDICTION PARAMETERS
REBAR SPACING INNER ROW (SLI), (in) 4.00
REBAR SPACING OUTER ROW (SLO), (in) 4.00
NUMBER OF STEEL LAYERS FOR INNER CAGE 1
NUMBER OF STEEL LAYERS FOR OUTER CAGE 1
HEGER-MCGRATH CODE NUMBER FOR STEEL TYPE.. 3

WALL THICKNESS, REBAR AREAS AND COVER DEPTHS

WALL-THICK	INNER-REBAR	OUTER-REBAR	INNER-COVER	OUTER COVER
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1100	0.1500	2.0000	2.4375
10.6250	0.1100	0.1500	2.0000	2.4375
12.3130	0.1100	0.1500	2.0000	2.4375
15.1250	0.1100	0.1500	2.0000	2.4375
19.1250	0.1100	0.1500	2.0000	2.4375
27.0000	0.1100	0.1500	2.0000	2.4375
18.3130	0.1100	0.1500	2.0000	2.4375
13.5630	0.1100	0.1500	2.0000	2.4375
12.0000	0.1100	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375

LRFD RESISTANCE FACTORS FOR STRENGTH-LIMIT STATES
AND CRACK-WIDTH LIMIT AT SERVICE LOAD

YIELDING OF REINFORCEMENT STEEL 1.000

CRUSHING OF CONCRETE OUTER FIBER..... 0.750

SHEARING FAILURE OF CONCRETE 0.900

SPLITTING OF CONCRETE IN RADIAL TENSION 0.900

ALLOWABLE CRACKWIDTH SERVICE LOAD (inch).... 0.010

LARGE DEFORMATION/BUCKLING CODE, IBUCK = 0
IBUCK=0, MEANS SMALL DEFORMATION THEORY FOR GROUP
AND NO BUCKLING PREDICTION.

28x10_3Axlec1Mod.out

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


 REVIEW SYSTEM INPUT DATA


 LEVEL-2 DATA FOR ARCH-TYPE CANNED MESH


    *** MESH PARAMETERS ***
     TYPE OF MESH ------------------------------------- TREN
     DEPTH OF TRENCH ABOVE FOOTING LEVEL (FT) ---------   12.42
     WIDTH OF TRENCH AT FOOTING LEVEL (FT) ------------    5.00
     SLOPE OF TRENCH WALL (H/V) -----------------------    0.00
     MESH SPACING PARAMETER ---------------------------    1.00
     TOTAL SOIL HEIGHT ABOVE CROWN (FT) ---------------    2.00
     MESH HEIGHT ABOVE CROWN (FT) ---------------------    2.00
     SOIL DENSITY ABOVE MESH (PCF) --------------------  140.00
     NUMBER OF ELEMENT LAYERS ABOVE CROWN -------------    3


*** ARCH PARAMETERS ***
     CENTERLINE RISE OF ARCH (IN) ---------------------  125.00
     BOTTOM HALF SPAN OF ARCH (IN) --------------------  174.00
     SIDE RISE OF ARCH ABOVE FOOTING (IN) -------------   50.94
     FOOTING DEPTH (IN) -------------------------------   24.00
     OUTSIDE FOOTING WIDTH (IN) -----------------------   30.00
     INSIDE FOOTING WIDTH (IN) ------------------------   30.00
     NUMBER OF ARCH SEGMENTS DEFINED ------------------    3

*** CURVED TOP SEGMENT ***
     RADIUS (IN) --------------------------------------  405.88
     CENTRAL ANGLE (DEG) ------------------------------   24.59
     SEGMENT ARC LENGTH (IN) --------------------------  174.19
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------   13

*** CURVED CORNER SEGMENT ***
     RADIUS (IN) --------------------------------------  133.94
     CENTRAL ANGLE (DEG) ------------------------------   16.14
     SEGMENT ARC LENGTH (IN) --------------------------   37.73
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------    3

*** STRAIGHT SIDE SEGMENT ***
     DEFLECTION ANGLE (DEG) ---------------------------   90.00
     SEGMENT LENGTH (IN) ------------------------------   50.94
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------    3

 FINITE ELEMENT INPUT CONTROLS (PREP)


THE DATA TO BE RUN IS ENTITLED ...

New Level 2 arch mesh

PRINT AND PLOT CONTROL CODES ...
  PRINT CONTROL FOR MESH DATA------------    1
  PLOT FILE CONTROL MESH & RESULS--------    3
  PRINT FINITE ELEMENT RESULTS ----------    1
  INPUT DATA CHECK CODE------------------    0
```

28x10_3Axlec1Mod.out

```
 KEY NUMBERS DESCRIBING MESH ...
   THE NUMBER OF LOAD STEPS IS------------   13
   TOTAL NUMBER OF NODES IS---------------  244
   TOTAL NUMBER OF ELEMENTS IS------------  209
   TOTAL NUMBER OF BEAM ELEMENTS IS-------   19
   MAX NUMBER OF BOUNDARY CONDITIONS IS---   36



  EXTENDED LEVEL-2: CHANGES TO CANNED MESH

           * NUMBER OF NODES TO BE CHANGED -------      0 *
           * NUMBER OF ELEMENTS TO BE CHANGED ----      0 *
           * ADDITIONAL BOUNDARY CONDITIONS ------     31 *



 * * * BOUNDARY CONDITIONS * * *
  (FORCES = LBS; DISPLACEMENTS = INCHES; ROTATIONS = DEGREES)

  BOUNDARY      LOAD      X-FORCE     OR      Y-FORCE     OR      X-Y ROTATION
BEAM ROTATIONAL
     NODE       STEP      X-DISPLACEMENT      Y-DISPLACEMENT
BOUNDARY CONDITIONS

      225        10    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      225        11    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      225        12    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      225        13    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        11    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        12    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        13    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      231        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      231        11    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      231        12    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      231        13    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      228        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
```

```
F
 231        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 232        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 233        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 224         9    F =   0.0000E+00    F =  -0.2188E+01      0.0000E+00
F
 225         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 226         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 227         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 228         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 229         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 230         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 231         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 232         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 233         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 234         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 235         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 236         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F

* * * * * COMPLETED MESH GENERATION  * * * * *

New Level 2 arch mesh

CALCULATED KEY NUMBERS ...
  THE NUMBER OF DATA ERRORS IS-----------    0
  THE NUMBER OF SOIL MATERIALS IS--------    3
  THE NUMBER OF PIPE-TYPE GROUPS IS------    1
  THE NUMBER OF INTERFACE MATERIALS IS---   19
  BAND WIDTH ESTIMATE (MAX)--------------   88


* * * * MESH DATA HAS BEEN SAVED ON UNIT 14 * * * *


 BEAM-NODE SEQUENCE NUMBERS FOR EACH GROUP


    BEAM-ELEMENT GROUP NUMBER =    1

     BEAM-NODE       MESH-NODE      CONNECTED-GROUP-ELEMENTS
     SEQUENCE        NUMBER         FOREWARD-#    BACKWARD-#
         1             198              1              0
         2             194              2              1
         3             190              3              2
         4             167              4              3
```

5	164	5	4
6	161	6	5
7	158	7	6
8	138	8	7
9	136	9	8
10	134	10	9
11	132	11	10
12	130	12	11
13	128	13	12
14	118	14	13
15	115	15	14
16	109	16	15
17	103	17	16
18	97	18	17
19	91	19	18
20	80	0	19

```
MATERIAL DESCRIPTION FOR SOILS AND INTERFACE
(ALL DENSITY UNITS ARE pcf, ALL MODULUS UNITS ARE psi)

   PROPERTIES FOR MATERIAL  1   ********in site

        DENSITY =    0.14000E+03

        YOUNGS MODULUS= 0.5000E+04
        POISSONS RATIO= 0.3500E+00
        CONFINED MOD.= 0.8025E+04
        LATERAL COEFF.= 0.5385E+00

   PROPERTIES FOR MATERIAL  2   ********Footing

        DENSITY =    0.15000E+03

        YOUNGS MODULUS= 0.3122E+07
        POISSONS RATIO= 0.1700E+00
        CONFINED MOD.= 0.3356E+07
        LATERAL COEFF.= 0.2048E+00

   PROPERTIES FOR MATERIAL  3   ********SW95

        DENSITY =    0.14000E+03

   CONTROLS FOR DUNCAN SOIL MODEL
   WITH SELIG HYPERBOLIC BULK MODULUS FORMULATION

         LRFD STRESS CONTROL..........        0

         ENTERING ELEMENT RATIO.......      0.5000


   HYPERBOLIC STRESS-STRAIN PARAMETERS


         SOIL CLASSIFICATION ............SW95
```

COHESION INTERCEPT C 0.0000

FRICTION ANGLE PHIO (DEG)..... 48.0000

10-FOLD REDUCTION IN PHIO(DEG).. 8.0000

SCALED MODULUS NUMBER ZK 950.0000

MODULUS EXPONENT ZN 0.6000

FAILURE RATIO RF 0.7000

INIT. BULK MODULUS NUMBER BI.... 74.8000

ULT. VOLUMETRIC STRAIN EU 0.0200

INTERFACE ELEMENT MATERIAL-GROUP PROPERTIES

MAT. NO.	NORMAL-ANGLE	COEF-FRICTION	TENSILE-RUPTURE	INITIAL-GAP
1	90.00	0.40000	10.00000	0.00000
2	88.11	0.40000	10.00000	0.00000
3	86.22	0.40000	10.00000	0.00000
4	84.32	0.40000	10.00000	0.00000
5	82.43	0.40000	10.00000	0.00000
6	80.54	0.40000	10.00000	0.00000
7	78.65	0.40000	10.00000	0.00000
8	76.76	0.40000	10.00000	0.00000
9	74.87	0.40000	10.00000	0.00000
10	72.97	0.40000	10.00000	0.00000
11	71.08	0.40000	10.00000	0.00000
12	69.19	0.40000	10.00000	0.00000
13	67.30	0.40000	10.00000	0.00000
14	65.41	0.40000	10.00000	0.00000
15	10.46	0.40000	10.00000	0.00000
16	5.11	0.40000	10.00000	0.00000
17	0.00	0.40000	10.00000	0.00000
18	0.00	0.40000	10.00000	0.00000
19	0.00	0.40000	10.00000	0.00000

LRFD TOTAL LOAD FACTORS PER LOAD STEP

LOAD STEP	LOAD FACTOR	USER COMMENT
1	1.310	Factor for load step #1
2	0.857	Factor for load step #2
3	0.857	Factor for load step #3
4	0.857	Factor for load step #4
5	1.365	Factor for load step #5
6	1.365	Factor for load step #6
7	1.365	Factor for load step #7

8	1.365	Factor for load step #8
9	1.500	Factor for load step #9
10	1.350	Factor for load step #10
11	1.350	Factor for load step #11
12	1.350	Factor for load step #12
13	1.350	Factor for load step #13

+ +

SOLUTION OUTPUT RESULTS

+ +

FINITE ELEMENT OUTPUT FOR LOAD STEP 13

+ +

CONCRETE, FACTORED-EVALUATION FOR GROUP 1, LOAD-STEP 13

STRUCTURAL RESPONSES OF CONCRETE-GROUP 1, LOAD-STEP 13
COORDINATES, DISPLACEMENTS AND CRACK DEPTHS ARE INCHES
Y-BAR IS "NEUTRAL AXIS" LOCATION FROM INTERIOR, INCHES
PRESSURES ARE LB/IN**2
MOMENTS ARE IN-LB/IN
THRUST AND SHEAR ARE LB/IN

LOCAL NODE	X-COORD. Y-COORD.	X-DISP. Y-DISP.	N-PRES. S-PRES.	MOMENT THRUST	Y-BAR CRACK DEPTH
1	0.00 125.00	0.00000E+00 -0.18097E+01	-0.29329E+02 0.46096E+01	0.42715E+05 -0.11377E+04	0.65484E+01 0.63552E+01
2	13.42 124.78	-0.25506E-03 -0.17904E+01	-0.22049E+02 -0.60590E+00	0.41163E+05 -0.11545E+04	0.65652E+01 0.63457E+01
3	26.80 124.11	0.19577E-02 -0.17341E+01	-0.14770E+02 -0.58214E+01	0.36005E+05 -0.12100E+04	0.66148E+01 0.63052E+01
4	40.15 123.01	0.86614E-02 -0.16456E+01	-0.94237E+01 -0.36945E+01	0.28575E+05 -0.12924E+04	0.66148E+01 0.62009E+01
5	53.46 121.47	0.21240E-01 -0.15317E+01	-0.42734E+01 -0.16358E+01	0.19869E+05 -0.13504E+04	0.65476E+01 0.59753E+01
6	66.71 119.48	0.40227E-01 -0.14008E+01	-0.89103E+00 -0.29390E+00	0.10840E+05 -0.13869E+04	0.65476E+01 0.54724E+01

7	79.89	0.65260E-01	-0.37213E+01	0.21107E+04	0.57292E+01
	117.06	-0.12615E+01	-0.14355E+01	-0.14224E+04	0.18703E+01
8	92.98	0.95131E-01	-0.35331E+01	-0.68132E+04	0.24151E+01
	114.21	-0.11223E+01	-0.13698E+01	-0.14656E+04	0.63166E+01
9	105.97	0.12760E+00	-0.46387E+01	-0.15874E+05	0.29481E+01
	110.92	-0.99160E+00	-0.18211E+01	-0.15124E+04	0.64628E+01
10	118.85	0.15931E+00	-0.56206E+01	-0.25252E+05	0.30809E+01
	107.21	-0.87883E+00	-0.22219E+01	-0.15661E+04	0.70620E+01
11	131.59	0.18737E+00	-0.66032E+01	-0.35110E+05	0.34674E+01
	103.08	-0.78981E+00	-0.26226E+01	-0.16272E+04	0.83405E+01
12	144.19	0.21089E+00	-0.77047E+01	-0.45619E+05	0.40809E+01
	98.53	-0.72263E+00	-0.30737E+01	-0.16969E+04	0.10418E+02
13	156.64	0.23051E+00	-0.91212E+01	-0.56986E+05	0.45666E+01
	93.56	-0.67176E+00	-0.19194E+01	-0.17662E+04	0.13445E+02
14	168.91	0.24756E+00	-0.11223E+02	-0.69496E+05	0.57315E+01
	88.19	-0.63144E+00	-0.55130E+01	-0.18893E+04	0.19445E+02
15	171.76	0.28023E+00	-0.85697E+01	-0.59699E+05	0.47460E+01
	75.95	-0.62325E+00	-0.23831E+01	-0.19677E+04	0.12775E+02
16	173.47	0.30242E+00	-0.10056E+02	-0.49002E+05	0.37441E+01
	63.50	-0.61951E+00	-0.25610E+01	-0.19379E+04	0.92997E+01
17	174.00	0.30578E+00	-0.10713E+02	-0.37623E+05	0.33970E+01
	50.94	-0.61856E+00	-0.27237E+00	-0.19120E+04	0.80921E+01
18	174.00	0.27664E+00	-0.67194E+01	-0.23578E+05	0.34814E+01
	33.96	-0.61741E+00	0.21220E+01	-0.18942E+04	0.76815E+01
19	174.00	0.22022E+00	-0.22187E+01	-0.11469E+05	0.36437E+01
	16.98	-0.61640E+00	0.56467E+00	-0.18890E+04	0.66853E+01
20	174.00	0.15302E+00	0.22820E+01	0.19077E-09	0.61687E+01
	0.00	-0.61575E+00	-0.99261E+00	-0.18971E+04	0.00000E+00

SHEAR FORCE DIAGNOSTCS FOR CONCRETE-GROUP 1, LOAD STEP 13
-- V-factor is coefficient of sqrt(PFPC) equal to capacity.
-- Shear depth "d" is negative if measured from outer wall.
-- Stirrup load is excess shear force above capacity.

NODE	EQUIVALENT V-factor	SHEAR CAPACITY lbs/inch	APPLIED SHEAR lbs/inch	APPLIED/ CAPACITY ratio	SHEAR DEPTH-d inches	STIRRUP LOAD lbs/inch
1	2.75	1770.72	-18.94	0.011	8.00	0.00
2	2.75	1772.13	250.34	0.141	8.00	0.00
3	2.75	1776.78	469.74	0.264	8.00	0.00
4	2.77	1783.68	602.11	0.338	8.00	0.00
5	2.77	1788.54	661.79	0.370	8.00	0.00
6	3.99	2574.98	662.70	0.257	8.00	0.00
7	4.50	2923.16	658.77	0.225	8.06	0.00
8	3.84	2361.26	671.14	0.284	-7.63	0.00

9	2.82	1736.77	688.12	0.396	-7.63	0.00
10	2.47	1627.48	717.82	0.441	-8.19	0.00
11	2.17	1727.40	759.99	0.440	-9.88	0.00
12	1.87	1914.13	816.30	0.426	-12.69	0.00
13	1.64	2205.37	891.04	0.404	-16.69	0.00
14	1.43	2830.57	76.84	0.027	-24.56	0.00
15	1.68	2156.42	-815.46	0.378	-15.88	0.00
16	2.03	1825.28	-877.98	0.481	-11.13	0.00
17	2.24	1727.65	-866.17	0.501	-9.56	0.00
18	2.30	1776.23	-770.18	0.434	-9.56	0.00
19	3.76	2900.26	-694.30	0.239	-9.56	0.00
20	4.50	3625.40	-656.62	0.181	10.00	0.00

STRESS AND STRAIN MEASURES FOR CONCRETE-GROUP 1, LOAD STEP 13

NODE	MAXIMUM COMPRESSION psi	AVERAGE SHEAR psi	RADIAL TENSION psi	INNER-WALL STRAIN in/in	OUTER-WALL STRAIN in/in
1	-3489.73	-2.43	14.86	0.1394E-02	-0.7836E-03
2	-3420.47	32.17	14.28	0.1340E-02	-0.7557E-03
3	-3142.64	60.37	12.38	0.1160E-02	-0.6641E-03
4	-2554.88	77.38	9.60	0.9075E-03	-0.5399E-03
5	-1856.18	85.05	6.34	0.6072E-03	-0.3922E-03
6	-1112.63	85.17	3.08	0.3063E-03	-0.2351E-03
7	-320.52	83.98	0.00	0.1546E-04	-0.6773E-04
8	-834.34	85.56	0.00	-0.1763E-03	0.3241E-03
9	-1770.26	87.72	0.00	-0.3741E-03	0.6995E-03
10	-2392.67	85.39	0.00	-0.5056E-03	0.1032E-02
11	-2404.11	75.29	0.00	-0.5080E-03	0.1098E-02
12	-2083.01	63.25	0.00	-0.4402E-03	0.1006E-02
13	-1689.38	52.70	0.00	-0.3570E-03	0.8787E-03
14	-1155.54	3.10	0.00	-0.2442E-03	0.6642E-03
15	-1930.35	-50.67	0.00	-0.4079E-03	0.9741E-03
16	-2747.20	-77.39	0.00	-0.5805E-03	0.1298E-02
17	-2735.71	-88.55	0.00	-0.5781E-03	0.1228E-02
18	-1902.60	-78.74	0.00	-0.4021E-03	0.7429E-03
19	-1032.35	-70.98	0.00	-0.2182E-03	0.2970E-03
20	-142.14	-67.13	0.00	-0.3004E-04	-0.3004E-04

STEEL STRESS AND CRACK WIDTHS FOR CONCRETE-GROUP 1, LOAD STEP 13
NOTE: CRACK WIDTH IS REDUCED TO SERVICE-LOAD LEVEL.
ALL OTHER RESPONSES ARE AT FACTORED LOAD LEVEL.

NODE	INNER CAGE psi	OUTER CAGE psi	MAX STRESS TO YIELD ratio	CRACK WIDTH inches
1	30540.76	-8058.83	0.5090	0.00683
2	29335.09	-7806.11	0.4889	0.00635
3	25350.13	-6991.25	0.4225	0.00480
4	19696.14	-5961.80	0.3283	0.00258
5	12980.10	-4736.49	0.2163	0.00000
6	6309.51	-3287.36	0.1052	0.00000
7	-34.17	-1516.28	0.0253	0.00000
8	-2449.02	6466.34	0.1078	0.00000
9	-5121.77	14003.82	0.2334	0.00000
10	-6889.49	21645.31	0.3608	0.00105

11	-7878.41	24850.01	0.4142	0.00148
12	-7932.14	24640.03	0.4107	0.00000
13	-7258.61	22983.47	0.3831	0.00000
14	-5637.29	18554.67	0.3092	0.00000
15	-8189.65	25179.45	0.4197	0.00000
16	-9671.96	30609.76	0.5102	0.00315
17	-8831.23	27437.36	0.4573	0.00267
18	-6731.18	16264.18	0.2711	0.00000
19	-4215.98	6130.01	0.1022	0.00000
20	-957.22	-957.22	0.0160	0.00000

ASSESSMENT SUMMARY CONCRETE-GROUP 1, LOAD-STEP 13

LRFD SUMMARY EVALUATION FOR GROUP 1, LOAD STEP 13

DESIGN-CRITERION	CONTROL NODE	FACTORED DEMAND	FACTORED CAPACITY	RATIO VALUE
STEEL YIELDING (psi)	16	30609.8	60000.0	0.510
CONCRETE CRUSHING (psi)	1	3489.7	4875.0	0.716
SHEAR FAILURE (lbs/in)	17	866.2	1554.9	0.557
RADIAL-TENSION FAIL (psi)	1	14.9	69.6	0.214

LRFD SERVICE-LOAD PERFORMANCE MEASURES FOR GROUP 1, LOAD STEP 13

NODE NUMBER FOR MAXIMUM CRACK WIDTH 1

MAXIMUM CRACK WIDTH AT SERVICE LOAD (inches) 0.00683

LRFD RATIO: MAX-CRACK-WIDTH / ALLOWABLE 0.68

SPAN LENGTH FOR AUXILIARY EQUATIONS (inches)..... 348.00

* * * * NORMAL EXIT FROM CANDE * * * *

28x10_3Axlec2Mod.out

```
*** WELCOME TO CANDE-2013(version 3/1/2013) ***

MASTER CONTROL AND PIPE-TYPE DATA FOR PROBLEM #  1

        USER TITLE: 28x10

        EXECUTION MODE ..................   ANALYS

        SOLUTION LEVEL ..................  #2 AUTO

        METHODOLOGY (LRFD OR SERVICE) ...     LRFD

        NUMBER OF PIPE-ELEMENT GROUPS ....       1

        MAXIMUM ITERATIONS PER STEP ......      30


        CULVERT PIPE-TYPE ............... CONCRETE

        CANNED MESH CODE # ..............        3

        NUMBER OF BEAM ELEMENTS .........       19

        CONCRETE MATERIAL PROPERTIES ARE AS FOLLOWS

             COMPRESSION STRENGTH (psi)..........       6500.000

             ELASTIC YOUNGS MODULUS (psi)........    4595487.000

             POISSON RATIO ......................          0.170

             CONCRETE DENSITY (pcf) .............        150.000

             INITIAL TENSILE CRACKING STRAIN.....       0.000010

             INITIAL COMPRESSION YIELD STRAIN....       0.000687

             INITIAL COMPRESSION CRUSH STRAIN ...       0.002000

             SHEAR STRENGTH MODEL (NSHEAR) # ...          1
             (VARIABLE STRENGTH MODEL PRINTED IN OUTPUT)

             CONCRETE CRACK-WIDTH MODEL NAME.....   HEGER-McGRATH
             (DRIVEN BY TENSILE STRAIN IN STEEL)

        STEEL REINFORCEMENT MATERIAL PROPERTIES

             TYPE OF STEEL CAGES (RSHAPE) .......     ARBIT

             STEEL YIELD STRENGTH (psi)..........      60000.000

             STEEL ELASTIC MODULUS (psi).........   29000000.000
```

28x10_3Axlec2Mod.out

STEEL POISSON RATIO 0.300000

STEEL YIELDING STRAIN 0.001883

NONLINEAR MODELING CODE (1,2,3) 3

STEEL-BASED CRACKWIDTH PREDICTION PARAMETERS

REBAR SPACING INNER ROW (SLI), (in)	4.00
REBAR SPACING OUTER ROW (SLO), (in)	4.00
NUMBER OF STEEL LAYERS FOR INNER CAGE	1
NUMBER OF STEEL LAYERS FOR OUTER CAGE	1
HEGER-MCGRATH CODE NUMBER FOR STEEL TYPE..	3

WALL THICKNESS, REBAR AREAS AND COVER DEPTHS

WALL-THICK	INNER-REBAR	OUTER-REBAR	INNER-COVER	OUTER COVER
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1100	0.1500	2.0000	2.4375
10.6250	0.1100	0.1500	2.0000	2.4375
12.3130	0.1100	0.1500	2.0000	2.4375
15.1250	0.1100	0.1500	2.0000	2.4375
19.1250	0.1100	0.1500	2.0000	2.4375
27.0000	0.1100	0.1500	2.0000	2.4375
18.3130	0.1100	0.1500	2.0000	2.4375
13.5630	0.1100	0.1500	2.0000	2.4375
12.0000	0.1100	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375

LRFD RESISTANCE FACTORS FOR STRENGTH-LIMIT STATES
AND CRACK-WIDTH LIMIT AT SERVICE LOAD

YIELDING OF REINFORCEMENT STEEL	1.000
CRUSHING OF CONCRETE OUTER FIBER.....	0.750
SHEARING FAILURE OF CONCRETE	0.900
SPLITTING OF CONCRETE IN RADIAL TENSION	0.900
ALLOWABLE CRACKWIDTH SERVICE LOAD (inch)....	0.010

LARGE DEFORMATION/BUCKLING CODE, IBUCK = 0
IBUCK=0, MEANS SMALL DEFORMATION THEORY FOR GROUP
AND NO BUCKLING PREDICTION.

28x10_3Axlec2Mod.out

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


 REVIEW SYSTEM INPUT DATA


 LEVEL-2 DATA FOR ARCH-TYPE CANNED MESH


    *** MESH PARAMETERS ***
     TYPE OF MESH ------------------------------------- TREN
     DEPTH OF TRENCH ABOVE FOOTING LEVEL (FT) ---------   12.42
     WIDTH OF TRENCH AT FOOTING LEVEL (FT) ------------    5.00
     SLOPE OF TRENCH WALL (H/V) -----------------------    0.00
     MESH SPACING PARAMETER ---------------------------    1.00
     TOTAL SOIL HEIGHT ABOVE CROWN (FT) ---------------    2.00
     MESH HEIGHT ABOVE CROWN (FT) ----------------------    2.00
     SOIL DENSITY ABOVE MESH (PCF) ---------------------  140.00
     NUMBER OF ELEMENT LAYERS ABOVE CROWN -------------    3


*** ARCH PARAMETERS ***
     CENTERLINE RISE OF ARCH (IN) ----------------------  125.00
     BOTTOM HALF SPAN OF ARCH (IN) ---------------------  174.00
     SIDE RISE OF ARCH ABOVE FOOTING (IN) -------------   50.94
     FOOTING DEPTH (IN) -------------------------------   24.00
     OUTSIDE FOOTING WIDTH (IN) -----------------------   30.00
     INSIDE FOOTING WIDTH (IN) ------------------------   30.00
     NUMBER OF ARCH SEGMENTS DEFINED ------------------    3

*** CURVED TOP SEGMENT ***
     RADIUS (IN) ---------------------------------------  405.88
     CENTRAL ANGLE (DEG) -------------------------------   24.59
     SEGMENT ARC LENGTH (IN) ---------------------------  174.19
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------   13

*** CURVED CORNER SEGMENT ***
     RADIUS (IN) ---------------------------------------  133.94
     CENTRAL ANGLE (DEG) -------------------------------   16.14
     SEGMENT ARC LENGTH (IN) ---------------------------   37.73
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------    3

*** STRAIGHT SIDE SEGMENT ***
     DEFLECTION ANGLE (DEG) ----------------------------   90.00
     SEGMENT LENGTH (IN) -------------------------------   50.94
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------    3

 FINITE ELEMENT INPUT CONTROLS (PREP)


THE DATA TO BE RUN IS ENTITLED ...

New Level 2 arch mesh

PRINT AND PLOT CONTROL CODES ...
  PRINT CONTROL FOR MESH DATA------------    1
  PLOT FILE CONTROL MESH & RESULS--------    3
  PRINT FINITE ELEMENT RESULTS ----------    1
  INPUT DATA CHECK CODE------------------    0
```

28x10_3Axlec2Mod.out

```
 KEY NUMBERS DESCRIBING MESH ...
   THE NUMBER OF LOAD STEPS IS------------   13
   TOTAL NUMBER OF NODES IS---------------  244
   TOTAL NUMBER OF ELEMENTS IS------------  209
   TOTAL NUMBER OF BEAM ELEMENTS IS-------   19
   MAX NUMBER OF BOUNDARY CONDITIONS IS---   36



  EXTENDED LEVEL-2: CHANGES TO CANNED MESH

           * NUMBER OF NODES TO BE CHANGED -------      0 *
           * NUMBER OF ELEMENTS TO BE CHANGED ----      0 *
           * ADDITIONAL BOUNDARY CONDITIONS ------     31 *



 * * * BOUNDARY CONDITIONS * * *
  (FORCES = LBS; DISPLACEMENTS = INCHES; ROTATIONS = DEGREES)

  BOUNDARY      LOAD      X-FORCE     OR      Y-FORCE     OR      X-Y ROTATION
BEAM ROTATIONAL
     NODE       STEP      X-DISPLACEMENT      Y-DISPLACEMENT
BOUNDARY CONDITIONS

      228        10    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      228        11    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      228        12    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      228        13    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      230        11    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      230        12    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      230        13    F =   0.0000E+00    F =  -0.1116E+03      0.0000E+00
     F
      231        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      231        11    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      231        12    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      231        13    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      228        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
```

```
F
 231        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 232        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 233        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 224         9    F =   0.0000E+00    F =  -0.2188E+01      0.0000E+00
F
 225         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 226         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 227         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 228         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 229         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 230         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 231         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 232         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 233         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 234         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 235         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 236         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F

* * * * * COMPLETED MESH GENERATION  * * * * *

New Level 2 arch mesh

CALCULATED KEY NUMBERS ...
  THE NUMBER OF DATA ERRORS IS-----------     0
  THE NUMBER OF SOIL MATERIALS IS--------     3
  THE NUMBER OF PIPE-TYPE GROUPS IS------     1
  THE NUMBER OF INTERFACE MATERIALS IS---    19
  BAND WIDTH ESTIMATE (MAX)--------------    88


* * * * MESH DATA HAS BEEN SAVED ON UNIT 14 * * * *


 BEAM-NODE SEQUENCE NUMBERS FOR EACH GROUP


    BEAM-ELEMENT GROUP NUMBER =    1

     BEAM-NODE       MESH-NODE      CONNECTED-GROUP-ELEMENTS
     SEQUENCE        NUMBER         FOREWARD-#     BACKWARD-#
         1             198              1              0
         2             194              2              1
         3             190              3              2
         4             167              4              3
```

5	164	5	4
6	161	6	5
7	158	7	6
8	138	8	7
9	136	9	8
10	134	10	9
11	132	11	10
12	130	12	11
13	128	13	12
14	118	14	13
15	115	15	14
16	109	16	15
17	103	17	16
18	97	18	17
19	91	19	18
20	80	0	19

```
MATERIAL DESCRIPTION FOR SOILS AND INTERFACE
(ALL DENSITY UNITS ARE pcf, ALL MODULUS UNITS ARE psi)

   PROPERTIES FOR MATERIAL  1   ********in site

        DENSITY =    0.14000E+03

        YOUNGS MODULUS= 0.5000E+04
        POISSONS RATIO= 0.3500E+00
        CONFINED MOD.= 0.8025E+04
        LATERAL COEFF.= 0.5385E+00

   PROPERTIES FOR MATERIAL  2   ********Footing

        DENSITY =    0.15000E+03

        YOUNGS MODULUS= 0.3122E+07
        POISSONS RATIO= 0.1700E+00
        CONFINED MOD.= 0.3356E+07
        LATERAL COEFF.= 0.2048E+00

   PROPERTIES FOR MATERIAL  3   ********SW95

        DENSITY =    0.14000E+03

   CONTROLS FOR DUNCAN SOIL MODEL
   WITH SELIG HYPERBOLIC BULK MODULUS FORMULATION

         LRFD STRESS CONTROL..........       0

         ENTERING ELEMENT RATIO.......      0.5000


   HYPERBOLIC STRESS-STRAIN PARAMETERS


         SOIL CLASSIFICATION ............SW95
```

COHESION INTERCEPT C 0.0000

FRICTION ANGLE PHIO (DEG)..... 48.0000

10-FOLD REDUCTION IN PHIO(DEG).. 8.0000

SCALED MODULUS NUMBER ZK 950.0000

MODULUS EXPONENT ZN 0.6000

FAILURE RATIO RF 0.7000

INIT. BULK MODULUS NUMBER BI.... 74.8000

ULT. VOLUMETRIC STRAIN EU 0.0200

INTERFACE ELEMENT MATERIAL-GROUP PROPERTIES

MAT. NO.	NORMAL-ANGLE	COEF-FRICTION	TENSILE-RUPTURE	INITIAL-GAP
1	90.00	0.40000	10.00000	0.00000
2	88.11	0.40000	10.00000	0.00000
3	86.22	0.40000	10.00000	0.00000
4	84.32	0.40000	10.00000	0.00000
5	82.43	0.40000	10.00000	0.00000
6	80.54	0.40000	10.00000	0.00000
7	78.65	0.40000	10.00000	0.00000
8	76.76	0.40000	10.00000	0.00000
9	74.87	0.40000	10.00000	0.00000
10	72.97	0.40000	10.00000	0.00000
11	71.08	0.40000	10.00000	0.00000
12	69.19	0.40000	10.00000	0.00000
13	67.30	0.40000	10.00000	0.00000
14	65.41	0.40000	10.00000	0.00000
15	10.46	0.40000	10.00000	0.00000
16	5.11	0.40000	10.00000	0.00000
17	0.00	0.40000	10.00000	0.00000
18	0.00	0.40000	10.00000	0.00000
19	0.00	0.40000	10.00000	0.00000

LRFD TOTAL LOAD FACTORS PER LOAD STEP

LOAD STEP	LOAD FACTOR	USER COMMENT
1	1.310	Factor for load step #1
2	0.857	Factor for load step #2
3	0.857	Factor for load step #3
4	0.857	Factor for load step #4
5	1.365	Factor for load step #5
6	1.365	Factor for load step #6
7	1.365	Factor for load step #7

28x10_3Axlec2Mod.out

8	1.365	Factor for load step #8
9	1.500	Factor for load step #9
10	1.350	Factor for load step #10
11	1.350	Factor for load step #11
12	1.350	Factor for load step #12
13	1.350	Factor for load step #13

+ +

SOLUTION OUTPUT RESULTS

+ +

FINITE ELEMENT OUTPUT FOR LOAD STEP 13

+ +

CONCRETE, FACTORED-EVALUATION FOR GROUP 1, LOAD-STEP 13

STRUCTURAL RESPONSES OF CONCRETE-GROUP 1, LOAD-STEP 13
COORDINATES, DISPLACEMENTS AND CRACK DEPTHS ARE INCHES
Y-BAR IS "NEUTRAL AXIS" LOCATION FROM INTERIOR, INCHES
PRESSURES ARE LB/IN**2
MOMENTS ARE IN-LB/IN
THRUST AND SHEAR ARE LB/IN

LOCAL NODE	X-COORD. Y-COORD.	X-DISP. Y-DISP.	N-PRES. S-PRES.	MOMENT THRUST	Y-BAR CRACK DEPTH
1	0.00	0.00000E+00	-0.31469E+01	0.23893E+05	0.66148E+01
	125.00	-0.18052E+01	-0.64539E+00	-0.14611E+04	0.60675E+01
2	13.42	-0.55932E-03	-0.29943E+01	0.23847E+05	0.66148E+01
	124.78	-0.17943E+01	-0.26834E+00	-0.14652E+04	0.60648E+01
3	26.80	0.31711E-03	-0.28418E+01	0.23755E+05	0.66148E+01
	124.11	-0.17618E+01	0.10872E+00	-0.14671E+04	0.60622E+01
4	40.15	0.40595E-02	-0.57140E+01	0.23647E+05	0.66148E+01
	123.01	-0.17078E+01	0.16105E+01	-0.14571E+04	0.60618E+01
5	53.46	0.12072E-01	-0.12159E+02	0.23002E+05	0.66148E+01
	121.47	-0.16327E+01	0.24444E+01	-0.14336E+04	0.60478E+01
6	66.71	0.25639E-01	-0.15651E+02	0.20655E+05	0.65476E+01
	119.48	-0.15377E+01	-0.63579E+00	-0.14294E+04	0.59718E+01

7	79.89	0.45578E-01	-0.19078E+02	0.15975E+05	0.65930E+01
	117.06	-0.14259E+01	-0.43523E+01	-0.14768E+04	0.57939E+01
8	92.98	0.71865E-01	-0.23964E+02	0.83681E+04	0.63124E+01
	114.21	-0.13029E+01	-0.95205E+01	-0.15915E+04	0.45619E+01
9	105.97	0.10354E+00	-0.13066E+02	-0.29891E+04	0.34272E+01
	110.92	-0.11753E+01	-0.43346E+01	-0.17140E+04	0.41326E+01
10	118.85	0.13820E+00	-0.19330E+02	-0.16087E+05	0.30809E+01
	107.21	-0.10521E+01	-0.77052E+01	-0.18310E+04	0.66776E+01
11	131.59	0.17219E+00	-0.72743E+01	-0.32009E+05	0.34674E+01
	103.08	-0.94433E+00	-0.28923E+01	-0.19441E+04	0.82001E+01
12	144.19	0.20307E+00	-0.79426E+01	-0.48562E+05	0.40809E+01
	98.53	-0.85639E+00	-0.31690E+01	-0.20312E+04	0.10359E+02
13	156.64	0.23042E+00	-0.84843E+01	-0.65869E+05	0.49117E+01
	93.56	-0.78583E+00	-0.34005E+01	-0.21256E+04	0.13382E+02
14	168.91	0.25523E+00	-0.98083E+01	-0.84045E+05	0.57315E+01
	88.19	-0.72752E+00	-0.98500E+01	-0.23802E+04	0.19442E+02
15	171.76	0.30428E+00	-0.84513E+01	-0.73107E+05	0.47460E+01
	75.95	-0.71532E+00	-0.25193E+01	-0.25685E+04	0.12756E+02
16	173.47	0.34064E+00	-0.10804E+02	-0.60550E+05	0.37867E+01
	63.50	-0.70943E+00	-0.28464E+01	-0.25278E+04	0.92826E+01
17	174.00	0.35379E+00	-0.12146E+02	-0.46731E+05	0.34351E+01
	50.94	-0.70782E+00	-0.51986E+00	-0.24933E+04	0.80777E+01
18	174.00	0.32969E+00	-0.81835E+01	-0.29333E+05	0.34814E+01
	33.96	-0.70631E+00	0.22792E+01	-0.24718E+04	0.76656E+01
19	174.00	0.27153E+00	-0.25826E+01	-0.14294E+05	0.36437E+01
	16.98	-0.70496E+00	0.71036E+00	-0.24641E+04	0.66853E+01
20	174.00	0.19987E+00	0.30182E+01	0.20896E-09	0.61687E+01
	0.00	-0.70411E+00	-0.85850E+00	-0.24697E+04	0.00000E+00

SHEAR FORCE DIAGNOSTCS FOR CONCRETE-GROUP 1, LOAD STEP 13
-- V-factor is coefficient of sqrt(PFPC) equal to capacity.
-- Shear depth "d" is negative if measured from outer wall.
-- Stirrup load is excess shear force above capacity.

NODE	EQUIVALENT V-factor	SHEAR CAPACITY lbs/inch	APPLIED SHEAR lbs/inch	APPLIED/ CAPACITY ratio	SHEAR DEPTH-d inches	STIRRUP LOAD lbs/inch
1	2.79	1797.81	1.64	0.001	8.00	0.00
2	2.79	1798.16	5.13	0.003	8.00	0.00
3	2.79	1798.31	7.47	0.004	8.00	0.00
4	2.79	1797.48	28.09	0.016	8.00	0.00
5	2.78	1795.51	111.66	0.062	8.00	0.00
6	2.78	1795.15	262.23	0.146	8.00	0.00
7	2.77	1801.07	458.49	0.255	8.06	0.00
8	4.50	2923.16	707.68	0.242	8.06	0.00

9	4.50	2764.55	912.61	0.330	-7.63	0.00
10	3.89	2569.79	1082.94	0.421	-8.19	0.00
11	2.53	2011.43	1211.85	0.602	-9.88	0.00
12	1.95	1996.60	1263.50	0.633	-12.69	0.00
13	1.71	2303.65	1324.12	0.575	-16.69	0.00
14	1.44	2855.44	242.86	0.085	-24.56	0.00
15	1.71	2189.99	-934.88	0.427	-15.88	0.00
16	2.08	1862.33	-1049.01	0.563	-11.13	0.00
17	2.29	1766.40	-1061.91	0.601	-9.56	0.00
18	2.36	1818.79	-955.18	0.525	-9.56	0.00
19	3.87	2981.85	-863.78	0.290	-9.56	0.00
20	4.50	3625.40	-819.93	0.226	10.00	0.00

STRESS AND STRAIN MEASURES FOR CONCRETE-GROUP 1, LOAD STEP 13

NODE	MAXIMUM COMPRESSION psi	AVERAGE SHEAR psi	RADIAL TENSION psi	INNER-WALL STRAIN in/in	OUTER-WALL STRAIN in/in
1	-2205.90	0.21	7.79	0.7446E-03	-0.4661E-03
2	-2203.08	0.66	7.77	0.7429E-03	-0.4655E-03
3	-2194.71	0.96	7.77	0.7394E-03	-0.4638E-03
4	-2183.26	3.61	7.71	0.7355E-03	-0.4614E-03
5	-2123.04	14.35	7.47	0.7118E-03	-0.4486E-03
6	-1928.48	33.70	6.55	0.6290E-03	-0.4075E-03
7	-1483.64	58.45	4.62	0.4491E-03	-0.3135E-03
8	-770.33	90.22	1.41	0.1533E-03	-0.1628E-03
9	-770.33	116.34	0.00	-0.1168E-03	0.8142E-04
10	-1674.75	128.83	0.00	-0.3539E-03	0.6256E-03
11	-2266.59	120.05	0.00	-0.4790E-03	0.9849E-03
12	-2248.69	97.90	0.00	-0.4752E-03	0.1065E-02
13	-1975.85	78.32	0.00	-0.4175E-03	0.1006E-02
14	-1410.17	9.80	0.00	-0.2980E-03	0.8022E-03
15	-2382.90	-58.09	0.00	-0.5035E-03	0.1189E-02
16	-3342.55	-92.47	0.00	-0.7242E-03	0.1602E-02
17	-3344.14	-108.57	0.00	-0.7248E-03	0.1523E-02
18	-2388.45	-97.65	0.00	-0.5047E-03	0.9203E-03
19	-1313.86	-88.31	0.00	-0.2776E-03	0.3718E-03
20	-185.04	-83.83	0.00	-0.3910E-04	-0.3910E-04

STEEL STRESS AND CRACK WIDTHS FOR CONCRETE-GROUP 1, LOAD STEP 13
NOTE: CRACK WIDTH IS REDUCED TO SERVICE-LOAD LEVEL.
ALL OTHER RESPONSES ARE AT FACTORED LOAD LEVEL.

NODE	INNER CAGE psi	OUTER CAGE psi	MAX STRESS TO YIELD ratio	CRACK WIDTH inches
1	16013.28	-5449.88	0.2669	0.00113
2	15972.68	-5449.03	0.2662	0.00112
3	15894.47	-5433.69	0.2649	0.00109
4	15811.11	-5405.47	0.2635	0.00106
5	15287.86	-5282.91	0.2548	0.00086
6	13437.82	-4935.61	0.2240	0.00014
7	9480.85	-4104.67	0.1580	0.00000
8	2883.01	-2747.79	0.0481	0.00000
9	-2467.96	1064.34	0.0411	0.00000
10	-5402.49	12775.46	0.2129	0.00000

11	-7686.50	22151.00	0.3692	0.00035
12	-8654.54	26019.22	0.4337	0.00042
13	-8561.37	26281.12	0.4380	0.00000
14	-6899.21	22400.51	0.3733	0.00000
15	-10157.01	30706.56	0.5118	0.00058
16	-12145.99	37734.60	0.6289	0.00613
17	-11158.12	33991.67	0.5665	0.00541
18	-8515.63	20103.76	0.3351	0.00000
19	-5398.36	7645.18	0.1274	0.00000
20	-1246.11	-1246.11	0.0208	0.00000

ASSESSMENT SUMMARY CONCRETE-GROUP 1, LOAD-STEP 13

LRFD SUMMARY EVALUATION FOR GROUP 1, LOAD STEP 13

DESIGN-CRITERION	CONTROL NODE	FACTORED DEMAND	FACTORED CAPACITY	RATIO VALUE
STEEL YIELDING (psi)	16	37734.6	60000.0	0.629
CONCRETE CRUSHING (psi)	17	3344.1	4875.0	0.686
SHEAR FAILURE (lbs/in)	12	1263.5	1796.9	0.703
RADIAL-TENSION FAIL (psi)	1	7.8	69.6	0.112

LRFD SERVICE-LOAD PERFORMANCE MEASURES FOR GROUP 1, LOAD STEP 13

NODE NUMBER FOR MAXIMUM CRACK WIDTH 16

MAXIMUM CRACK WIDTH AT SERVICE LOAD (inches) 0.00613

LRFD RATIO: MAX-CRACK-WIDTH / ALLOWABLE 0.61

SPAN LENGTH FOR AUXILIARY EQUATIONS (inches)..... 348.00

* * * * NORMAL EXIT FROM CANDE * * * *

28x10_4Axlec1Mod.out

```
*** WELCOME TO CANDE-2013(version 3/1/2013) ***

MASTER CONTROL AND PIPE-TYPE DATA FOR PROBLEM #  1

        USER TITLE: 28x10

        EXECUTION MODE ..................   ANALYS

        SOLUTION LEVEL ..................  #2 AUTO

        METHODOLOGY (LRFD OR SERVICE) ...     LRFD

        NUMBER OF PIPE-ELEMENT GROUPS ....       1

        MAXIMUM ITERATIONS PER STEP ......      30


        CULVERT PIPE-TYPE ............... CONCRETE

        CANNED MESH CODE # ..............        3

        NUMBER OF BEAM ELEMENTS .........       19

        CONCRETE MATERIAL PROPERTIES ARE AS FOLLOWS

             COMPRESSION STRENGTH (psi)..........       6500.000

             ELASTIC YOUNGS MODULUS (psi)........    4595487.000

             POISSON RATIO ......................          0.170

             CONCRETE DENSITY (pcf) .............        150.000

             INITIAL TENSILE CRACKING STRAIN.....       0.000010

             INITIAL COMPRESSION YIELD STRAIN....       0.000687

             INITIAL COMPRESSION CRUSH STRAIN ...       0.002000

             SHEAR STRENGTH MODEL (NSHEAR) # ...          1
             (VARIABLE STRENGTH MODEL PRINTED IN OUTPUT)

             CONCRETE CRACK-WIDTH MODEL NAME.....   HEGER-McGRATH
             (DRIVEN BY TENSILE STRAIN IN STEEL)

        STEEL REINFORCEMENT MATERIAL PROPERTIES

             TYPE OF STEEL CAGES (RSHAPE) .......     ARBIT

             STEEL YIELD STRENGTH (psi)..........      60000.000

             STEEL ELASTIC MODULUS (psi).........   29000000.000
```

28x10_4Axlec1Mod.out

STEEL POISSON RATIO 0.300000

STEEL YIELDING STRAIN 0.001883

NONLINEAR MODELING CODE (1,2,3) 3

STEEL-BASED CRACKWIDTH PREDICTION PARAMETERS
REBAR SPACING INNER ROW (SLI), (in) 4.00
REBAR SPACING OUTER ROW (SLO), (in) 4.00
NUMBER OF STEEL LAYERS FOR INNER CAGE 1
NUMBER OF STEEL LAYERS FOR OUTER CAGE 1
HEGER-MCGRATH CODE NUMBER FOR STEEL TYPE.. 3

WALL THICKNESS, REBAR AREAS AND COVER DEPTHS

WALL-THICK	INNER-REBAR	OUTER-REBAR	INNER-COVER	OUTER COVER
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1100	0.1500	2.0000	2.4375
10.6250	0.1100	0.1500	2.0000	2.4375
12.3130	0.1100	0.1500	2.0000	2.4375
15.1250	0.1100	0.1500	2.0000	2.4375
19.1250	0.1100	0.1500	2.0000	2.4375
27.0000	0.1100	0.1500	2.0000	2.4375
18.3130	0.1100	0.1500	2.0000	2.4375
13.5630	0.1100	0.1500	2.0000	2.4375
12.0000	0.1100	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375

LRFD RESISTANCE FACTORS FOR STRENGTH-LIMIT STATES
AND CRACK-WIDTH LIMIT AT SERVICE LOAD

YIELDING OF REINFORCEMENT STEEL 1.000

CRUSHING OF CONCRETE OUTER FIBER..... 0.750

SHEARING FAILURE OF CONCRETE 0.900

SPLITTING OF CONCRETE IN RADIAL TENSION 0.900

ALLOWABLE CRACKWIDTH SERVICE LOAD (inch).... 0.010

LARGE DEFORMATION/BUCKLING CODE, IBUCK = 0
IBUCK=0, MEANS SMALL DEFORMATION THEORY FOR GROUP
AND NO BUCKLING PREDICTION.

28x10_4Axle1Mod.out

```
REVIEW SYSTEM INPUT DATA


LEVEL-2 DATA FOR ARCH-TYPE CANNED MESH


    *** MESH PARAMETERS ***
     TYPE OF MESH ------------------------------------- TREN
     DEPTH OF TRENCH ABOVE FOOTING LEVEL (FT) ---------   12.42
     WIDTH OF TRENCH AT FOOTING LEVEL (FT) ------------    5.00
     SLOPE OF TRENCH WALL (H/V) -----------------------    0.00
     MESH SPACING PARAMETER ---------------------------    1.00
     TOTAL SOIL HEIGHT ABOVE CROWN (FT) ---------------    2.00
     MESH HEIGHT ABOVE CROWN (FT) ---------------------    2.00
     SOIL DENSITY ABOVE MESH (PCF) --------------------  140.00
     NUMBER OF ELEMENT LAYERS ABOVE CROWN -------------    3


*** ARCH PARAMETERS ***
     CENTERLINE RISE OF ARCH (IN) ---------------------  125.00
     BOTTOM HALF SPAN OF ARCH (IN) --------------------  174.00
     SIDE RISE OF ARCH ABOVE FOOTING (IN) -------------   50.94
     FOOTING DEPTH (IN) -------------------------------   24.00
     OUTSIDE FOOTING WIDTH (IN) -----------------------   30.00
     INSIDE FOOTING WIDTH (IN) ------------------------   30.00
     NUMBER OF ARCH SEGMENTS DEFINED ------------------    3

*** CURVED TOP SEGMENT ***
     RADIUS (IN) --------------------------------------  405.88
     CENTRAL ANGLE (DEG) ------------------------------   24.59
     SEGMENT ARC LENGTH (IN) --------------------------  174.19
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------   13

*** CURVED CORNER SEGMENT ***
     RADIUS (IN) --------------------------------------  133.94
     CENTRAL ANGLE (DEG) ------------------------------   16.14
     SEGMENT ARC LENGTH (IN) --------------------------   37.73
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------    3

*** STRAIGHT SIDE SEGMENT ***
     DEFLECTION ANGLE (DEG) ---------------------------   90.00
     SEGMENT LENGTH (IN) ------------------------------   50.94
     NUMBER OF BEAM ELEMENTS IN SEGMENT ---------------    3

 FINITE ELEMENT INPUT CONTROLS (PREP)


THE DATA TO BE RUN IS ENTITLED ...

New Level 2 arch mesh

PRINT AND PLOT CONTROL CODES ...
  PRINT CONTROL FOR MESH DATA------------     1
  PLOT FILE CONTROL MESH & RESULS--------     3
  PRINT FINITE ELEMENT RESULTS ----------     1
  INPUT DATA CHECK CODE------------------     0
```

28x10_4Axlec1Mod.out

```
KEY NUMBERS DESCRIBING MESH ...
  THE NUMBER OF LOAD STEPS IS------------   13
  TOTAL NUMBER OF NODES IS---------------  244
  TOTAL NUMBER OF ELEMENTS IS------------  209
  TOTAL NUMBER OF BEAM ELEMENTS IS-------   19
  MAX NUMBER OF BOUNDARY CONDITIONS IS---   36



 EXTENDED LEVEL-2: CHANGES TO CANNED MESH

          * NUMBER OF NODES TO BE CHANGED -------      0 *
          * NUMBER OF ELEMENTS TO BE CHANGED ----      0 *
          * ADDITIONAL BOUNDARY CONDITIONS ------     31 *



 * * * BOUNDARY CONDITIONS * * *
  (FORCES = LBS; DISPLACEMENTS = INCHES; ROTATIONS = DEGREES)

  BOUNDARY      LOAD      X-FORCE     OR      Y-FORCE     OR      X-Y ROTATION
BEAM ROTATIONAL
     NODE       STEP      X-DISPLACEMENT      Y-DISPLACEMENT
BOUNDARY CONDITIONS

      225        10    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      225        11    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      225        12    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      225        13    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      228        10    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      228        11    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      228        12    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      228        13    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      231        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      231        11    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      231        12    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      231        13    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      228        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
```

```
F
 231        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 232        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 233        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 224         9    F =   0.0000E+00    F =  -0.2188E+01      0.0000E+00
F
 225         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 226         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 227         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 228         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 229         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 230         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 231         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 232         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 233         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 234         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 235         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 236         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F

* * * * * COMPLETED MESH GENERATION  * * * * *

New Level 2 arch mesh

CALCULATED KEY NUMBERS ...
  THE NUMBER OF DATA ERRORS IS-----------    0
  THE NUMBER OF SOIL MATERIALS IS--------    3
  THE NUMBER OF PIPE-TYPE GROUPS IS------    1
  THE NUMBER OF INTERFACE MATERIALS IS---   19
  BAND WIDTH ESTIMATE (MAX)--------------   88


* * * * MESH DATA HAS BEEN SAVED ON UNIT 14 * * * *


 BEAM-NODE SEQUENCE NUMBERS FOR EACH GROUP


    BEAM-ELEMENT GROUP NUMBER =    1

     BEAM-NODE       MESH-NODE      CONNECTED-GROUP-ELEMENTS
     SEQUENCE        NUMBER         FOREWARD-#     BACKWARD-#
         1             198              1              0
         2             194              2              1
         3             190              3              2
         4             167              4              3
```

5	164	5	4
6	161	6	5
7	158	7	6
8	138	8	7
9	136	9	8
10	134	10	9
11	132	11	10
12	130	12	11
13	128	13	12
14	118	14	13
15	115	15	14
16	109	16	15
17	103	17	16
18	97	18	17
19	91	19	18
20	80	0	19

```
MATERIAL DESCRIPTION FOR SOILS AND INTERFACE
(ALL DENSITY UNITS ARE pcf, ALL MODULUS UNITS ARE psi)

   PROPERTIES FOR MATERIAL  1   ********in site

        DENSITY =    0.14000E+03

        YOUNGS MODULUS= 0.5000E+04
        POISSONS RATIO= 0.3500E+00
        CONFINED MOD.= 0.8025E+04
        LATERAL COEFF.= 0.5385E+00

   PROPERTIES FOR MATERIAL  2   ********Footing

        DENSITY =    0.15000E+03

        YOUNGS MODULUS= 0.3122E+07
        POISSONS RATIO= 0.1700E+00
        CONFINED MOD.= 0.3356E+07
        LATERAL COEFF.= 0.2048E+00

   PROPERTIES FOR MATERIAL  3   ********SW95

        DENSITY =    0.14000E+03

   CONTROLS FOR DUNCAN SOIL MODEL
   WITH SELIG HYPERBOLIC BULK MODULUS FORMULATION

         LRFD STRESS CONTROL..........       0

         ENTERING ELEMENT RATIO.......      0.5000


   HYPERBOLIC STRESS-STRAIN PARAMETERS


         SOIL CLASSIFICATION .............SW95
```

COHESION INTERCEPT C 0.0000

FRICTION ANGLE PHIO (DEG)..... 48.0000

10-FOLD REDUCTION IN PHIO(DEG).. 8.0000

SCALED MODULUS NUMBER ZK 950.0000

MODULUS EXPONENT ZN 0.6000

FAILURE RATIO RF 0.7000

INIT. BULK MODULUS NUMBER BI.... 74.8000

ULT. VOLUMETRIC STRAIN EU 0.0200

INTERFACE ELEMENT MATERIAL-GROUP PROPERTIES

MAT. NO.	NORMAL-ANGLE	COEF-FRICTION	TENSILE-RUPTURE	INITIAL-GAP
1	90.00	0.40000	10.00000	0.00000
2	88.11	0.40000	10.00000	0.00000
3	86.22	0.40000	10.00000	0.00000
4	84.32	0.40000	10.00000	0.00000
5	82.43	0.40000	10.00000	0.00000
6	80.54	0.40000	10.00000	0.00000
7	78.65	0.40000	10.00000	0.00000
8	76.76	0.40000	10.00000	0.00000
9	74.87	0.40000	10.00000	0.00000
10	72.97	0.40000	10.00000	0.00000
11	71.08	0.40000	10.00000	0.00000
12	69.19	0.40000	10.00000	0.00000
13	67.30	0.40000	10.00000	0.00000
14	65.41	0.40000	10.00000	0.00000
15	10.46	0.40000	10.00000	0.00000
16	5.11	0.40000	10.00000	0.00000
17	0.00	0.40000	10.00000	0.00000
18	0.00	0.40000	10.00000	0.00000
19	0.00	0.40000	10.00000	0.00000

LRFD TOTAL LOAD FACTORS PER LOAD STEP

LOAD STEP	LOAD FACTOR	USER COMMENT
1	1.310	Factor for load step #1
2	0.857	Factor for load step #2
3	0.857	Factor for load step #3
4	0.857	Factor for load step #4
5	1.365	Factor for load step #5
6	1.365	Factor for load step #6
7	1.365	Factor for load step #7

28x10_4Axle c1Mod.out

8	1.365	Factor for load step #8
9	1.500	Factor for load step #9
10	1.350	Factor for load step #10
11	1.350	Factor for load step #11
12	1.350	Factor for load step #12
13	1.350	Factor for load step #13

\+ +

SOLUTION OUTPUT RESULTS

\+ +

FINITE ELEMENT OUTPUT FOR LOAD STEP 13

\+ +

CONCRETE, FACTORED-EVALUATION FOR GROUP 1, LOAD-STEP 13

STRUCTURAL RESPONSES OF CONCRETE-GROUP 1, LOAD-STEP 13
COORDINATES, DISPLACEMENTS AND CRACK DEPTHS ARE INCHES
Y-BAR IS "NEUTRAL AXIS" LOCATION FROM INTERIOR, INCHES
PRESSURES ARE LB/IN**2
MOMENTS ARE IN-LB/IN
THRUST AND SHEAR ARE LB/IN

LOCAL NODE	X-COORD. Y-COORD.	X-DISP. Y-DISP.	N-PRES. S-PRES.	MOMENT THRUST	Y-BAR CRACK DEPTH
1	0.00	0.00000E+00	-0.24174E+02	0.42735E+05	0.65420E+01
	125.00	-0.20402E+01	0.26487E+01	-0.13735E+04	0.63120E+01
2	13.42	-0.37726E-03	-0.17388E+02	0.41426E+05	0.65556E+01
	124.78	-0.20208E+01	-0.53836E+00	-0.13876E+04	0.63026E+01
3	26.80	0.17374E-02	-0.10603E+02	0.37452E+05	0.66056E+01
	124.11	-0.19640E+01	-0.37254E+01	-0.14258E+04	0.62715E+01
4	40.15	0.84966E-02	-0.86359E+01	0.32050E+05	0.66148E+01
	123.01	-0.18736E+01	-0.33745E+01	-0.14874E+04	0.61991E+01
5	53.46	0.21563E-01	-0.12335E+02	0.25599E+05	0.66148E+01
	121.47	-0.17546E+01	-0.20654E+01	-0.15415E+04	0.60736E+01
6	66.71	0.41953E-01	-0.12755E+02	0.17463E+05	0.65476E+01
	119.48	-0.16136E+01	-0.41933E+01	-0.16052E+04	0.57963E+01

7	79.89	0.69725E-01	-0.11856E+02	0.75924E+04	0.63124E+01
	117.06	-0.14588E+01	-0.46869E+01	-0.16910E+04	0.45780E+01
8	92.98	0.10386E+00	-0.10929E+02	-0.38145E+04	0.46761E+01
	114.21	-0.12999E+01	-0.43291E+01	-0.17819E+04	0.35995E+00
9	105.97	0.14253E+00	-0.35785E+01	-0.16547E+05	0.29481E+01
	110.92	-0.11445E+01	-0.13953E+01	-0.18537E+04	0.63653E+01
10	118.85	0.18177E+00	-0.59127E+01	-0.29254E+05	0.30809E+01
	107.21	-0.10049E+01	-0.23385E+01	-0.19137E+04	0.70488E+01
11	131.59	0.21712E+00	-0.66726E+01	-0.42339E+05	0.34674E+01
	103.08	-0.89287E+00	-0.26509E+01	-0.19837E+04	0.83489E+01
12	144.19	0.24719E+00	-0.77337E+01	-0.55931E+05	0.40809E+01
	98.53	-0.80713E+00	-0.30855E+01	-0.20613E+04	0.10442E+02
13	156.64	0.27259E+00	-0.94175E+01	-0.70225E+05	0.45666E+01
	93.56	-0.74139E+00	-0.27932E+01	-0.21438E+04	0.13488E+02
14	168.91	0.29490E+00	-0.11902E+02	-0.85548E+05	0.57315E+01
	88.19	-0.68868E+00	-0.52294E+01	-0.22830E+04	0.19552E+02
15	171.76	0.33812E+00	-0.99148E+01	-0.73555E+05	0.47460E+01
	75.95	-0.67790E+00	-0.24592E+01	-0.23602E+04	0.12818E+02
16	173.47	0.36845E+00	-0.11915E+02	-0.60416E+05	0.37773E+01
	63.50	-0.67290E+00	-0.26145E+01	-0.23133E+04	0.93229E+01
17	174.00	0.37556E+00	-0.12634E+02	-0.46444E+05	0.34234E+01
	50.94	-0.67164E+00	-0.11229E+00	-0.22728E+04	0.81176E+01
18	174.00	0.34355E+00	-0.82616E+01	-0.29120E+05	0.34814E+01
	33.96	-0.67027E+00	0.27630E+01	-0.22441E+04	0.77310E+01
19	174.00	0.27773E+00	-0.26518E+01	-0.14177E+05	0.36437E+01
	16.98	-0.66906E+00	0.73814E+00	-0.22321E+04	0.68116E+01
20	174.00	0.19851E+00	0.29580E+01	0.27444E-09	0.61687E+01
	0.00	-0.66829E+00	-0.12867E+01	-0.22372E+04	0.00000E+00

SHEAR FORCE DIAGNOSTCS FOR CONCRETE-GROUP 1, LOAD STEP 13
-- V-factor is coefficient of sqrt(PFPC) equal to capacity.
-- Shear depth "d" is negative if measured from outer wall.
-- Stirrup load is excess shear force above capacity.

NODE	EQUIVALENT V-factor	SHEAR CAPACITY lbs/inch	APPLIED SHEAR lbs/inch	APPLIED/ CAPACITY ratio	SHEAR DEPTH-d inches	STIRRUP LOAD lbs/inch
1	2.78	1790.47	-2.01	0.001	8.00	0.00
2	2.78	1791.66	197.08	0.110	8.00	0.00
3	2.78	1794.85	349.90	0.195	8.00	0.00
4	2.79	1800.01	442.28	0.246	8.00	0.00
5	2.80	1804.55	544.33	0.302	8.00	0.00
6	2.84	1832.88	671.98	0.367	8.00	0.00
7	4.50	2923.16	794.00	0.272	8.06	0.00
8	4.50	2764.55	900.78	0.326	-7.63	0.00

9	3.55	2179.70	949.34	0.436	-7.63	0.00
10	2.50	1652.27	962.53	0.583	-8.19	0.00
11	2.20	1750.85	995.49	0.569	-9.88	0.00
12	1.89	1935.96	1040.56	0.537	-12.69	0.00
13	1.65	2226.18	1105.23	0.496	-16.69	0.00
14	1.44	2850.52	94.38	0.033	-24.56	0.00
15	1.70	2178.35	-1000.05	0.459	-15.88	0.00
16	2.06	1848.86	-1078.24	0.583	-11.13	0.00
17	2.27	1751.70	-1065.81	0.608	-9.56	0.00
18	2.33	1792.84	-950.16	0.530	-9.56	0.00
19	3.79	2918.37	-857.51	0.294	-9.56	0.00
20	4.50	3625.40	-812.48	0.224	10.00	0.00

STRESS AND STRAIN MEASURES FOR CONCRETE-GROUP 1, LOAD STEP 13

NODE	MAXIMUM COMPRESSION psi	AVERAGE SHEAR psi	RADIAL TENSION psi	INNER-WALL STRAIN in/in	OUTER-WALL STRAIN in/in
1	-3514.90	-0.26	14.73	0.1386E-02	-0.7938E-03
2	-3456.55	25.33	14.24	0.1340E-02	-0.7702E-03
3	-3278.10	44.97	12.79	0.1201E-02	-0.6981E-03
4	-2873.10	56.84	10.75	0.1017E-02	-0.6071E-03
5	-2353.38	69.95	8.35	0.7947E-03	-0.4973E-03
6	-1694.27	86.36	5.32	0.5174E-03	-0.3580E-03
7	-813.06	101.22	1.48	0.1617E-03	-0.1718E-03
8	-340.79	114.83	0.00	-0.7201E-04	0.1304E-04
9	-1897.18	121.02	0.00	-0.4009E-03	0.7173E-03
10	-2789.78	114.50	0.00	-0.5895E-03	0.1192E-02
11	-2902.63	98.62	0.00	-0.6134E-03	0.1323E-02
12	-2551.22	80.62	0.00	-0.5391E-03	0.1234E-02
13	-2077.31	65.37	0.00	-0.4390E-03	0.1084E-02
14	-1419.87	3.81	0.00	-0.3000E-03	0.8239E-03
15	-2370.69	-62.14	0.00	-0.5010E-03	0.1202E-02
16	-3320.60	-95.05	0.00	-0.7153E-03	0.1605E-02
17	-3313.32	-108.96	0.00	-0.7124E-03	0.1520E-02
18	-2334.26	-97.14	0.00	-0.4933E-03	0.9214E-03
19	-1270.20	-87.67	0.00	-0.2684E-03	0.3755E-03
20	-167.62	-83.07	0.00	-0.3542E-04	-0.3542E-04

STEEL STRESS AND CRACK WIDTHS FOR CONCRETE-GROUP 1, LOAD STEP 13
NOTE: CRACK WIDTH IS REDUCED TO SERVICE-LOAD LEVEL.
ALL OTHER RESPONSES ARE AT FACTORED LOAD LEVEL.

NODE	INNER CAGE psi	OUTER CAGE psi	MAX STRESS TO YIELD ratio	CRACK WIDTH inches
1	30269.10	-8366.95	0.5045	0.00672
2	29252.92	-8154.12	0.4875	0.00632
3	26171.51	-7495.25	0.4362	0.00512
4	22046.13	-6735.82	0.3674	0.00351
5	17091.70	-5811.85	0.2849	0.00157
6	10910.10	-4609.09	0.1818	0.00000
7	3041.84	-2900.52	0.0507	0.00000
8	-1756.25	-240.94	0.0293	0.00000
9	-5693.42	14228.23	0.2371	0.00000
10	-8102.17	24954.19	0.4159	0.00244

11	-9524.16	29943.42	0.4991	0.00361
12	-9707.24	30228.06	0.5038	0.00219
13	-8912.46	28369.22	0.4728	0.00000
14	-6908.58	23022.22	0.3837	0.00000
15	-10038.70	31075.35	0.5179	0.00073
16	-11892.71	37853.75	0.6309	0.00618
17	-10842.84	33998.49	0.5666	0.00541
18	-8205.74	20205.63	0.3368	0.00000
19	-5133.69	7798.69	0.1300	0.00000
20	-1128.80	-1128.80	0.0188	0.00000

ASSESSMENT SUMMARY CONCRETE-GROUP 1, LOAD-STEP 13

LRFD SUMMARY EVALUATION FOR GROUP 1, LOAD STEP 13

DESIGN-CRITERION	CONTROL NODE	FACTORED DEMAND	FACTORED CAPACITY	RATIO VALUE
STEEL YIELDING (psi)	16	37853.8	60000.0	0.631
CONCRETE CRUSHING (psi)	1	3514.9	4875.0	0.721
SHEAR FAILURE (lbs/in)	17	1065.8	1576.5	0.676
RADIAL-TENSION FAIL (psi)	1	14.7	69.6	0.212

LRFD SERVICE-LOAD PERFORMANCE MEASURES FOR GROUP 1, LOAD STEP 13

NODE NUMBER FOR MAXIMUM CRACK WIDTH 1

MAXIMUM CRACK WIDTH AT SERVICE LOAD (inches) 0.00672

LRFD RATIO: MAX-CRACK-WIDTH / ALLOWABLE 0.67

SPAN LENGTH FOR AUXILIARY EQUATIONS (inches)..... 348.00

* * * * NORMAL EXIT FROM CANDE * * * *

28x10_4Axlec2Mod.out

```
*** WELCOME TO CANDE-2013(version 3/1/2013) ***

MASTER CONTROL AND PIPE-TYPE DATA FOR PROBLEM #  1

        USER TITLE: 28x10

        EXECUTION MODE ..................   ANALYS

        SOLUTION LEVEL ..................  #2 AUTO

        METHODOLOGY (LRFD OR SERVICE) ...     LRFD

        NUMBER OF PIPE-ELEMENT GROUPS ....       1

        MAXIMUM ITERATIONS PER STEP ......      30


        CULVERT PIPE-TYPE ............... CONCRETE

        CANNED MESH CODE # ..............        3

        NUMBER OF BEAM ELEMENTS .........       19

        CONCRETE MATERIAL PROPERTIES ARE AS FOLLOWS

             COMPRESSION STRENGTH (psi)..........       6500.000

             ELASTIC YOUNGS MODULUS (psi)........    4595487.000

             POISSON RATIO ......................          0.170

             CONCRETE DENSITY (pcf) .............        150.000

             INITIAL TENSILE CRACKING STRAIN.....       0.000010

             INITIAL COMPRESSION YIELD STRAIN....       0.000687

             INITIAL COMPRESSION CRUSH STRAIN ...       0.002000

             SHEAR STRENGTH MODEL (NSHEAR) # ...          1
             (VARIABLE STRENGTH MODEL PRINTED IN OUTPUT)

             CONCRETE CRACK-WIDTH MODEL NAME.....   HEGER-McGRATH
             (DRIVEN BY TENSILE STRAIN IN STEEL)

        STEEL REINFORCEMENT MATERIAL PROPERTIES

             TYPE OF STEEL CAGES (RSHAPE) .......     ARBIT

             STEEL YIELD STRENGTH (psi)..........      60000.000

             STEEL ELASTIC MODULUS (psi).........   29000000.000
```

28x10_4Axlec2Mod.out

STEEL POISSON RATIO 0.300000

STEEL YIELDING STRAIN 0.001883

NONLINEAR MODELING CODE (1,2,3) 3

STEEL-BASED CRACKWIDTH PREDICTION PARAMETERS
REBAR SPACING INNER ROW (SLI), (in) 4.00
REBAR SPACING OUTER ROW (SLO), (in) 4.00
NUMBER OF STEEL LAYERS FOR INNER CAGE 1
NUMBER OF STEEL LAYERS FOR OUTER CAGE 1
HEGER-MCGRATH CODE NUMBER FOR STEEL TYPE.. 3

WALL THICKNESS, REBAR AREAS AND COVER DEPTHS

WALL-THICK	INNER-REBAR	OUTER-REBAR	INNER-COVER	OUTER COVER
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1100	0.1500	2.0000	2.4375
10.6250	0.1100	0.1500	2.0000	2.4375
12.3130	0.1100	0.1500	2.0000	2.4375
15.1250	0.1100	0.1500	2.0000	2.4375
19.1250	0.1100	0.1500	2.0000	2.4375
27.0000	0.1100	0.1500	2.0000	2.4375
18.3130	0.1100	0.1500	2.0000	2.4375
13.5630	0.1100	0.1500	2.0000	2.4375
12.0000	0.1100	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375

LRFD RESISTANCE FACTORS FOR STRENGTH-LIMIT STATES
AND CRACK-WIDTH LIMIT AT SERVICE LOAD

YIELDING OF REINFORCEMENT STEEL 1.000

CRUSHING OF CONCRETE OUTER FIBER..... 0.750

SHEARING FAILURE OF CONCRETE 0.900

SPLITTING OF CONCRETE IN RADIAL TENSION 0.900

ALLOWABLE CRACKWIDTH SERVICE LOAD (inch).... 0.010

LARGE DEFORMATION/BUCKLING CODE, IBUCK = 0
IBUCK=0, MEANS SMALL DEFORMATION THEORY FOR GROUP
AND NO BUCKLING PREDICTION.

28x10_4Axlec2Mod.out

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


 REVIEW SYSTEM INPUT DATA


 LEVEL-2 DATA FOR ARCH-TYPE CANNED MESH


    *** MESH PARAMETERS ***
     TYPE OF MESH ------------------------------------- TREN
     DEPTH OF TRENCH ABOVE FOOTING LEVEL (FT) ---------   12.42
     WIDTH OF TRENCH AT FOOTING LEVEL (FT) ------------    5.00
     SLOPE OF TRENCH WALL (H/V) -----------------------    0.00
     MESH SPACING PARAMETER ---------------------------    1.00
     TOTAL SOIL HEIGHT ABOVE CROWN (FT) ---------------    2.00
     MESH HEIGHT ABOVE CROWN (FT) ----------------------    2.00
     SOIL DENSITY ABOVE MESH (PCF) ---------------------  140.00
     NUMBER OF ELEMENT LAYERS ABOVE CROWN -------------    3


*** ARCH PARAMETERS ***
     CENTERLINE RISE OF ARCH (IN) ----------------------  125.00
     BOTTOM HALF SPAN OF ARCH (IN) ---------------------  174.00
     SIDE RISE OF ARCH ABOVE FOOTING (IN) -------------   50.94
     FOOTING DEPTH (IN) --------------------------------   24.00
     OUTSIDE FOOTING WIDTH (IN) ------------------------   30.00
     INSIDE FOOTING WIDTH (IN) -------------------------   30.00
     NUMBER OF ARCH SEGMENTS DEFINED -------------------    3

*** CURVED TOP SEGMENT ***
     RADIUS (IN) ---------------------------------------  405.88
     CENTRAL ANGLE (DEG) -------------------------------   24.59
     SEGMENT ARC LENGTH (IN) ---------------------------  174.19
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------   13

*** CURVED CORNER SEGMENT ***
     RADIUS (IN) ---------------------------------------  133.94
     CENTRAL ANGLE (DEG) -------------------------------   16.14
     SEGMENT ARC LENGTH (IN) ---------------------------   37.73
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

*** STRAIGHT SIDE SEGMENT ***
     DEFLECTION ANGLE (DEG) ----------------------------   90.00
     SEGMENT LENGTH (IN) -------------------------------   50.94
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

 FINITE ELEMENT INPUT CONTROLS (PREP)


THE DATA TO BE RUN IS ENTITLED ...

New Level 2 arch mesh

PRINT AND PLOT CONTROL CODES ...
  PRINT CONTROL FOR MESH DATA------------    1
  PLOT FILE CONTROL MESH & RESULS--------    3
  PRINT FINITE ELEMENT RESULTS ----------    1
  INPUT DATA CHECK CODE------------------    0
```

28x10_4Axlec2Mod.out

```
KEY NUMBERS DESCRIBING MESH ...
  THE NUMBER OF LOAD STEPS IS------------   13
  TOTAL NUMBER OF NODES IS---------------  244
  TOTAL NUMBER OF ELEMENTS IS------------  209
  TOTAL NUMBER OF BEAM ELEMENTS IS-------   19
  MAX NUMBER OF BOUNDARY CONDITIONS IS---   36


 EXTENDED LEVEL-2: CHANGES TO CANNED MESH

          * NUMBER OF NODES TO BE CHANGED -------      0 *
          * NUMBER OF ELEMENTS TO BE CHANGED ----      0 *
          * ADDITIONAL BOUNDARY CONDITIONS ------     31 *


 * * * BOUNDARY CONDITIONS * * *
  (FORCES = LBS; DISPLACEMENTS = INCHES; ROTATIONS = DEGREES)

  BOUNDARY      LOAD      X-FORCE     OR      Y-FORCE     OR      X-Y ROTATION
BEAM ROTATIONAL
     NODE       STEP      X-DISPLACEMENT      Y-DISPLACEMENT
BOUNDARY CONDITIONS

      227        10    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      227        11    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      227        12    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      227        13    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      229        11    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      229        12    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      229        13    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      231        10    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      231        11    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      231        12    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      231        13    F =   0.0000E+00    F =  -0.8833E+02      0.0000E+00
     F
      228        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
```

```
F
 231        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 232        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 233        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 224         9    F =   0.0000E+00    F =  -0.2188E+01      0.0000E+00
F
 225         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 226         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 227         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 228         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 229         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 230         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 231         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 232         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 233         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 234         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 235         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 236         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F

* * * * * COMPLETED MESH GENERATION  * * * * *

New Level 2 arch mesh

CALCULATED KEY NUMBERS ...
  THE NUMBER OF DATA ERRORS IS-----------    0
  THE NUMBER OF SOIL MATERIALS IS--------    3
  THE NUMBER OF PIPE-TYPE GROUPS IS------    1
  THE NUMBER OF INTERFACE MATERIALS IS---   19
  BAND WIDTH ESTIMATE (MAX)--------------   88


* * * * MESH DATA HAS BEEN SAVED ON UNIT 14 * * * *


 BEAM-NODE SEQUENCE NUMBERS FOR EACH GROUP


    BEAM-ELEMENT GROUP NUMBER =    1

     BEAM-NODE       MESH-NODE      CONNECTED-GROUP-ELEMENTS
     SEQUENCE        NUMBER         FOREWARD-#     BACKWARD-#
         1             198              1              0
         2             194              2              1
         3             190              3              2
         4             167              4              3
```

5	164	5	4
6	161	6	5
7	158	7	6
8	138	8	7
9	136	9	8
10	134	10	9
11	132	11	10
12	130	12	11
13	128	13	12
14	118	14	13
15	115	15	14
16	109	16	15
17	103	17	16
18	97	18	17
19	91	19	18
20	80	0	19

```
MATERIAL DESCRIPTION FOR SOILS AND INTERFACE
(ALL DENSITY UNITS ARE pcf, ALL MODULUS UNITS ARE psi)

   PROPERTIES FOR MATERIAL  1   ********in site

        DENSITY =    0.14000E+03

        YOUNGS MODULUS= 0.5000E+04
        POISSONS RATIO= 0.3500E+00
        CONFINED MOD.= 0.8025E+04
        LATERAL COEFF.= 0.5385E+00

   PROPERTIES FOR MATERIAL  2   ********Footing

        DENSITY =    0.15000E+03

        YOUNGS MODULUS= 0.3122E+07
        POISSONS RATIO= 0.1700E+00
        CONFINED MOD.= 0.3356E+07
        LATERAL COEFF.= 0.2048E+00

   PROPERTIES FOR MATERIAL  3   ********SW95

        DENSITY =    0.14000E+03

   CONTROLS FOR DUNCAN SOIL MODEL
   WITH SELIG HYPERBOLIC BULK MODULUS FORMULATION

         LRFD STRESS CONTROL..........        0

         ENTERING ELEMENT RATIO.......      0.5000


   HYPERBOLIC STRESS-STRAIN PARAMETERS


         SOIL CLASSIFICATION ............SW95
```

COHESION INTERCEPT C 0.0000

FRICTION ANGLE PHIO (DEG)..... 48.0000

10-FOLD REDUCTION IN PHIO(DEG).. 8.0000

SCALED MODULUS NUMBER ZK 950.0000

MODULUS EXPONENT ZN 0.6000

FAILURE RATIO RF 0.7000

INIT. BULK MODULUS NUMBER BI.... 74.8000

ULT. VOLUMETRIC STRAIN EU 0.0200

INTERFACE ELEMENT MATERIAL-GROUP PROPERTIES

MAT. NO.	NORMAL-ANGLE	COEF-FRICTION	TENSILE-RUPTURE	INITIAL-GAP
1	90.00	0.40000	10.00000	0.00000
2	88.11	0.40000	10.00000	0.00000
3	86.22	0.40000	10.00000	0.00000
4	84.32	0.40000	10.00000	0.00000
5	82.43	0.40000	10.00000	0.00000
6	80.54	0.40000	10.00000	0.00000
7	78.65	0.40000	10.00000	0.00000
8	76.76	0.40000	10.00000	0.00000
9	74.87	0.40000	10.00000	0.00000
10	72.97	0.40000	10.00000	0.00000
11	71.08	0.40000	10.00000	0.00000
12	69.19	0.40000	10.00000	0.00000
13	67.30	0.40000	10.00000	0.00000
14	65.41	0.40000	10.00000	0.00000
15	10.46	0.40000	10.00000	0.00000
16	5.11	0.40000	10.00000	0.00000
17	0.00	0.40000	10.00000	0.00000
18	0.00	0.40000	10.00000	0.00000
19	0.00	0.40000	10.00000	0.00000

LRFD TOTAL LOAD FACTORS PER LOAD STEP

LOAD STEP	LOAD FACTOR	USER COMMENT
1	1.310	Factor for load step #1
2	0.857	Factor for load step #2
3	0.857	Factor for load step #3
4	0.857	Factor for load step #4
5	1.365	Factor for load step #5
6	1.365	Factor for load step #6
7	1.365	Factor for load step #7

8	1.365	Factor for load step #8
9	1.500	Factor for load step #9
10	1.350	Factor for load step #10
11	1.350	Factor for load step #11
12	1.350	Factor for load step #12
13	1.350	Factor for load step #13

+ +

SOLUTION OUTPUT RESULTS

+ +

FINITE ELEMENT OUTPUT FOR LOAD STEP 13

+ +

CONCRETE, FACTORED-EVALUATION FOR GROUP 1, LOAD-STEP 13

STRUCTURAL RESPONSES OF CONCRETE-GROUP 1, LOAD-STEP 13
COORDINATES, DISPLACEMENTS AND CRACK DEPTHS ARE INCHES
Y-BAR IS "NEUTRAL AXIS" LOCATION FROM INTERIOR, INCHES
PRESSURES ARE LB/IN**2
MOMENTS ARE IN-LB/IN
THRUST AND SHEAR ARE LB/IN

LOCAL NODE	X-COORD. Y-COORD.	X-DISP. Y-DISP.	N-PRES. S-PRES.	MOMENT THRUST	Y-BAR CRACK DEPTH
1	0.00 125.00	0.00000E+00 -0.19824E+01	0.35071E+00 -0.86360E+00	0.28474E+05 -0.15951E+04	0.66148E+01 0.61195E+01
2	13.42 124.78	-0.59199E-03 -0.19694E+01	-0.28947E+01 0.41103E+00	0.28516E+05 -0.15898E+04	0.66148E+01 0.61214E+01
3	26.80 124.11	0.53713E-03 -0.19305E+01	-0.61401E+01 0.16857E+01	0.28584E+05 -0.15765E+04	0.66148E+01 0.61263E+01
4	40.15 123.01	0.51032E-02 -0.18658E+01	-0.12403E+02 0.19403E+01	0.28093E+05 -0.15551E+04	0.66148E+01 0.61220E+01
5	53.46 121.47	0.14741E-01 -0.17763E+01	-0.14195E+02 -0.14497E+01	0.25907E+05 -0.15587E+04	0.66148E+01 0.60752E+01
6	66.71 119.48	0.30777E-01 -0.16643E+01	-0.15748E+02 -0.34868E+01	0.21708E+05 -0.16040E+04	0.65476E+01 0.59443E+01

7	79.89	0.53899E-01	-0.18273E+02	0.15237E+05	0.65930E+01
	117.06	-0.15346E+01	-0.71385E+01	-0.16935E+04	0.56497E+01
8	92.98	0.83774E-01	-0.13736E+02	0.60790E+04	0.56843E+01
	114.21	-0.13950E+01	-0.22591E+01	-0.17810E+04	0.28614E+01
9	105.97	0.11910E+00	-0.21298E+02	-0.49088E+04	0.33080E+01
	110.92	-0.12528E+01	-0.84753E+01	-0.18837E+04	0.49553E+01
10	118.85	0.15720E+00	-0.11777E+02	-0.19040E+05	0.30809E+01
	107.21	-0.11172E+01	-0.33873E+01	-0.20004E+04	0.67527E+01
11	131.59	0.19428E+00	-0.17958E+02	-0.34564E+05	0.34674E+01
	103.08	-0.99969E+00	-0.71566E+01	-0.21142E+04	0.82023E+01
12	144.19	0.22792E+00	-0.96875E+01	-0.52563E+05	0.40809E+01
	98.53	-0.90384E+00	-0.38661E+01	-0.22370E+04	0.10356E+02
13	156.64	0.25778E+00	-0.10395E+02	-0.71537E+05	0.49117E+01
	93.56	-0.82681E+00	-0.41656E+01	-0.23454E+04	0.13381E+02
14	168.91	0.28485E+00	-0.11010E+02	-0.91626E+05	0.57315E+01
	88.19	-0.76309E+00	-0.89602E+01	-0.26174E+04	0.19467E+02
15	171.76	0.33841E+00	-0.93519E+01	-0.79717E+05	0.47460E+01
	75.95	-0.74974E+00	-0.25294E+01	-0.28120E+04	0.12762E+02
16	173.47	0.37811E+00	-0.11905E+02	-0.66047E+05	0.38483E+01
	63.50	-0.74330E+00	-0.27687E+01	-0.27627E+04	0.92768E+01
17	174.00	0.39243E+00	-0.13059E+02	-0.51011E+05	0.34892E+01
	50.94	-0.74154E+00	-0.29900E+00	-0.27196E+04	0.80740E+01
18	174.00	0.36595E+00	-0.88528E+01	-0.32036E+05	0.34814E+01
	33.96	-0.73990E+00	0.26610E+01	-0.26913E+04	0.76749E+01
19	174.00	0.30221E+00	-0.28077E+01	-0.15613E+05	0.36437E+01
	16.98	-0.73842E+00	0.80046E+00	-0.26796E+04	0.67144E+01
20	174.00	0.22368E+00	0.32374E+01	0.77989E-10	0.61687E+01
	0.00	-0.73749E+00	-0.10601E+01	-0.26837E+04	0.00000E+00

SHEAR FORCE DIAGNOSTCS FOR CONCRETE-GROUP 1, LOAD STEP 13
-- V-factor is coefficient of sqrt(PFPC) equal to capacity.
-- Shear depth "d" is negative if measured from outer wall.
-- Stirrup load is excess shear force above capacity.

NODE	EQUIVALENT V-factor	SHEAR CAPACITY lbs/inch	APPLIED SHEAR lbs/inch	APPLIED/ CAPACITY ratio	SHEAR DEPTH-d inches	STIRRUP LOAD lbs/inch
1	2.80	1809.03	-2.16	0.001	8.00	0.00
2	2.80	1808.59	-4.11	0.002	8.00	0.00
3	2.80	1807.48	15.79	0.009	8.00	0.00
4	2.80	1805.68	99.91	0.055	8.00	0.00
5	2.80	1805.99	238.26	0.132	8.00	0.00
6	2.81	1809.78	398.16	0.220	8.00	0.00
7	2.88	1875.35	583.22	0.311	8.06	0.00
8	4.50	2923.16	751.78	0.257	8.06	0.00
9	4.50	2764.55	937.39	0.339	-7.63	0.00

10	3.55	2342.21	1106.66	0.472	-8.19	0.00
11	2.46	1960.76	1250.94	0.638	-9.88	0.00
12	1.98	2023.88	1379.67	0.682	-12.69	0.00
13	1.74	2340.73	1457.75	0.623	-16.69	0.00
14	1.45	2867.45	275.60	0.096	-24.56	0.00
15	1.72	2203.59	-1017.83	0.462	-15.88	0.00
16	2.09	1877.08	-1141.69	0.608	-11.13	0.00
17	2.31	1781.50	-1156.75	0.649	-9.56	0.00
18	2.38	1832.31	-1042.37	0.569	-9.56	0.00
19	3.90	3003.87	-943.38	0.314	-9.56	0.00
20	4.50	3625.40	-895.71	0.247	10.00	0.00

STRESS AND STRAIN MEASURES FOR CONCRETE-GROUP 1, LOAD STEP 13

NODE	MAXIMUM COMPRESSION psi	AVERAGE SHEAR psi	RADIAL TENSION psi	INNER-WALL STRAIN in/in	OUTER-WALL STRAIN in/in
1	-2602.81	-0.28	9.38	0.8931E-03	-0.5500E-03
2	-2605.37	-0.53	9.39	0.8947E-03	-0.5506E-03
3	-2607.24	2.03	9.46	0.8972E-03	-0.5510E-03
4	-2564.07	12.84	9.27	0.8811E-03	-0.5418E-03
5	-2381.36	30.62	8.45	0.8044E-03	-0.5032E-03
6	-2043.95	51.17	6.83	0.6577E-03	-0.4319E-03
7	-1459.03	74.35	4.24	0.4175E-03	-0.3083E-03
8	-551.10	95.84	0.39	0.6025E-04	-0.1165E-03
9	-779.67	119.50	0.00	-0.1648E-03	0.1598E-03
10	-1952.07	131.65	0.00	-0.4125E-03	0.7468E-03
11	-2449.96	123.93	0.00	-0.5177E-03	0.1063E-02
12	-2439.30	106.90	0.00	-0.5155E-03	0.1151E-02
13	-2150.15	86.23	0.00	-0.4544E-03	0.1092E-02
14	-1543.03	11.12	0.00	-0.3261E-03	0.8785E-03
15	-2599.72	-63.24	0.00	-0.5494E-03	0.1296E-02
16	-3517.21	-100.64	0.00	-0.7947E-03	0.1752E-02
17	-3519.83	-118.26	0.00	-0.7958E-03	0.1667E-02
18	-2607.55	-106.57	0.00	-0.5510E-03	0.1006E-02
19	-1437.15	-96.45	0.00	-0.3037E-03	0.4085E-03
20	-201.07	-91.57	0.00	-0.4249E-04	-0.4249E-04

STEEL STRESS AND CRACK WIDTHS FOR CONCRETE-GROUP 1, LOAD STEP 13
NOTE: CRACK WIDTH IS REDUCED TO SERVICE-LOAD LEVEL.
ALL OTHER RESPONSES ARE AT FACTORED LOAD LEVEL.

NODE	INNER CAGE psi	OUTER CAGE psi	MAX STRESS TO YIELD ratio	CRACK WIDTH inches
1	19264.41	-6317.80	0.3211	0.00241
2	19300.76	-6318.69	0.3217	0.00242
3	19360.88	-6309.13	0.3227	0.00245
4	19010.82	-6213.66	0.3168	0.00232
5	17300.39	-5879.27	0.2883	0.00165
6	14014.99	-5300.41	0.2336	0.00037
7	8707.68	-4222.76	0.1451	0.00000
8	800.74	-2347.22	0.0391	0.00000
9	-3194.57	2588.24	0.0532	0.00000
10	-6191.41	15323.44	0.2554	0.00000
11	-8316.39	23903.19	0.3984	0.00108

12	-9403.64	28126.73	0.4688	0.00131
13	-9326.83	28514.15	0.4752	0.00000
14	-7547.51	24531.93	0.4089	0.00000
15	-11084.52	33474.11	0.5579	0.00174
16	-13360.54	41239.84	0.6873	0.00760
17	-12279.13	37186.11	0.6198	0.00675
18	-9292.52	21968.40	0.3661	0.00042
19	-5895.48	8407.60	0.1401	0.00000
20	-1354.06	-1354.06	0.0226	0.00000

ASSESSMENT SUMMARY CONCRETE-GROUP 1, LOAD-STEP 13

LRFD SUMMARY EVALUATION FOR GROUP 1, LOAD STEP 13

DESIGN-CRITERION	CONTROL NODE	FACTORED DEMAND	FACTORED CAPACITY	RATIO VALUE
STEEL YIELDING (psi)	16	41239.8	60000.0	0.687
CONCRETE CRUSHING (psi)	17	3519.8	4875.0	0.722
SHEAR FAILURE (lbs/in)	12	1379.7	1821.5	0.757
RADIAL-TENSION FAIL (psi)	3	9.5	69.6	0.136

LRFD SERVICE-LOAD PERFORMANCE MEASURES FOR GROUP 1, LOAD STEP 13

NODE NUMBER FOR MAXIMUM CRACK WIDTH 16

MAXIMUM CRACK WIDTH AT SERVICE LOAD (inches) 0.00760

LRFD RATIO: MAX-CRACK-WIDTH / ALLOWABLE 0.76

SPAN LENGTH FOR AUXILIARY EQUATIONS (inches)..... 348.00

* * * * NORMAL EXIT FROM CANDE * * * *

28x10_5Axlec1Mod.out

```
*** WELCOME TO CANDE-2013(version 3/1/2013) ***

MASTER CONTROL AND PIPE-TYPE DATA FOR PROBLEM #  1

        USER TITLE: 28x10

        EXECUTION MODE ..................   ANALYS

        SOLUTION LEVEL ..................  #2 AUTO

        METHODOLOGY (LRFD OR SERVICE) ...     LRFD

        NUMBER OF PIPE-ELEMENT GROUPS ....       1

        MAXIMUM ITERATIONS PER STEP ......      30


        CULVERT PIPE-TYPE ............... CONCRETE

        CANNED MESH CODE # ..............        3

        NUMBER OF BEAM ELEMENTS .........       19

        CONCRETE MATERIAL PROPERTIES ARE AS FOLLOWS

             COMPRESSION STRENGTH (psi)..........       6500.000

             ELASTIC YOUNGS MODULUS (psi)........    4595487.000

             POISSON RATIO ......................          0.170

             CONCRETE DENSITY (pcf) .............        150.000

             INITIAL TENSILE CRACKING STRAIN.....       0.000010

             INITIAL COMPRESSION YIELD STRAIN....       0.000687

             INITIAL COMPRESSION CRUSH STRAIN ...       0.002000

             SHEAR STRENGTH MODEL (NSHEAR) # ...          1
             (VARIABLE STRENGTH MODEL PRINTED IN OUTPUT)

             CONCRETE CRACK-WIDTH MODEL NAME.....   HEGER-McGRATH
             (DRIVEN BY TENSILE STRAIN IN STEEL)

        STEEL REINFORCEMENT MATERIAL PROPERTIES

             TYPE OF STEEL CAGES (RSHAPE) .......     ARBIT

             STEEL YIELD STRENGTH (psi)..........      60000.000

             STEEL ELASTIC MODULUS (psi).........   29000000.000
```

28x10_5Axlec1Mod.out

STEEL POISSON RATIO 0.300000

STEEL YIELDING STRAIN 0.001883

NONLINEAR MODELING CODE (1,2,3) 3

STEEL-BASED CRACKWIDTH PREDICTION PARAMETERS

REBAR SPACING INNER ROW (SLI), (in)	4.00
REBAR SPACING OUTER ROW (SLO), (in)	4.00
NUMBER OF STEEL LAYERS FOR INNER CAGE	1
NUMBER OF STEEL LAYERS FOR OUTER CAGE	1
HEGER-MCGRATH CODE NUMBER FOR STEEL TYPE..	3

WALL THICKNESS, REBAR AREAS AND COVER DEPTHS

WALL-THICK	INNER-REBAR	OUTER-REBAR	INNER-COVER	OUTER COVER
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1100	0.1500	2.0000	2.4375
10.6250	0.1100	0.1500	2.0000	2.4375
12.3130	0.1100	0.1500	2.0000	2.4375
15.1250	0.1100	0.1500	2.0000	2.4375
19.1250	0.1100	0.1500	2.0000	2.4375
27.0000	0.1100	0.1500	2.0000	2.4375
18.3130	0.1100	0.1500	2.0000	2.4375
13.5630	0.1100	0.1500	2.0000	2.4375
12.0000	0.1100	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375

LRFD RESISTANCE FACTORS FOR STRENGTH-LIMIT STATES
AND CRACK-WIDTH LIMIT AT SERVICE LOAD

YIELDING OF REINFORCEMENT STEEL	1.000
CRUSHING OF CONCRETE OUTER FIBER.....	0.750
SHEARING FAILURE OF CONCRETE	0.900
SPLITTING OF CONCRETE IN RADIAL TENSION	0.900
ALLOWABLE CRACKWIDTH SERVICE LOAD (inch)....	0.010

LARGE DEFORMATION/BUCKLING CODE, IBUCK = 0
IBUCK=0, MEANS SMALL DEFORMATION THEORY FOR GROUP
AND NO BUCKLING PREDICTION.

28x10_5Axlec1Mod.out

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


 REVIEW SYSTEM INPUT DATA


 LEVEL-2 DATA FOR ARCH-TYPE CANNED MESH


    *** MESH PARAMETERS ***
     TYPE OF MESH ------------------------------------- TREN
     DEPTH OF TRENCH ABOVE FOOTING LEVEL (FT) ---------   12.42
     WIDTH OF TRENCH AT FOOTING LEVEL (FT) ------------    5.00
     SLOPE OF TRENCH WALL (H/V) -----------------------    0.00
     MESH SPACING PARAMETER ---------------------------    1.00
     TOTAL SOIL HEIGHT ABOVE CROWN (FT) ---------------    2.00
     MESH HEIGHT ABOVE CROWN (FT) ----------------------    2.00
     SOIL DENSITY ABOVE MESH (PCF) --------------------  140.00
     NUMBER OF ELEMENT LAYERS ABOVE CROWN -------------    3


*** ARCH PARAMETERS ***
     CENTERLINE RISE OF ARCH (IN) ----------------------  125.00
     BOTTOM HALF SPAN OF ARCH (IN) ---------------------  174.00
     SIDE RISE OF ARCH ABOVE FOOTING (IN) -------------   50.94
     FOOTING DEPTH (IN) --------------------------------   24.00
     OUTSIDE FOOTING WIDTH (IN) ------------------------   30.00
     INSIDE FOOTING WIDTH (IN) -------------------------   30.00
     NUMBER OF ARCH SEGMENTS DEFINED -------------------    3

*** CURVED TOP SEGMENT ***
     RADIUS (IN) ---------------------------------------  405.88
     CENTRAL ANGLE (DEG) -------------------------------   24.59
     SEGMENT ARC LENGTH (IN) ---------------------------  174.19
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------   13

*** CURVED CORNER SEGMENT ***
     RADIUS (IN) ---------------------------------------  133.94
     CENTRAL ANGLE (DEG) -------------------------------   16.14
     SEGMENT ARC LENGTH (IN) ---------------------------   37.73
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

*** STRAIGHT SIDE SEGMENT ***
     DEFLECTION ANGLE (DEG) ----------------------------   90.00
     SEGMENT LENGTH (IN) -------------------------------   50.94
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

 FINITE ELEMENT INPUT CONTROLS (PREP)


THE DATA TO BE RUN IS ENTITLED ...

New Level 2 arch mesh

PRINT AND PLOT CONTROL CODES ...
  PRINT CONTROL FOR MESH DATA------------    1
  PLOT FILE CONTROL MESH & RESULS--------    3
  PRINT FINITE ELEMENT RESULTS ----------    1
  INPUT DATA CHECK CODE------------------    0
```

28x10_5Axlec1Mod.out

```
KEY NUMBERS DESCRIBING MESH ...
  THE NUMBER OF LOAD STEPS IS------------   13
  TOTAL NUMBER OF NODES IS---------------  244
  TOTAL NUMBER OF ELEMENTS IS------------  209
  TOTAL NUMBER OF BEAM ELEMENTS IS-------   19
  MAX NUMBER OF BOUNDARY CONDITIONS IS---   36


 EXTENDED LEVEL-2: CHANGES TO CANNED MESH

          * NUMBER OF NODES TO BE CHANGED -------      0 *
          * NUMBER OF ELEMENTS TO BE CHANGED ----      0 *
          * ADDITIONAL BOUNDARY CONDITIONS ------     31 *


* * * BOUNDARY CONDITIONS * * *
 (FORCES = LBS; DISPLACEMENTS = INCHES; ROTATIONS = DEGREES)

 BOUNDARY      LOAD      X-FORCE     OR      Y-FORCE     OR      X-Y ROTATION
BEAM ROTATIONAL
    NODE       STEP      X-DISPLACEMENT      Y-DISPLACEMENT
BOUNDARY CONDITIONS

      225        10    F =   0.0000E+00    F =  -0.7903E+02      0.0000E+00
     F
      225        11    F =   0.0000E+00    F =  -0.7903E+02      0.0000E+00
     F
      225        12    F =   0.0000E+00    F =  -0.7903E+02      0.0000E+00
     F
      225        13    F =   0.0000E+00    F =  -0.7903E+02      0.0000E+00
     F
      232        10    F =   0.0000E+00    F =  -0.3719E+02      0.0000E+00
     F
      232        11    F =   0.0000E+00    F =  -0.3719E+02      0.0000E+00
     F
      232        12    F =   0.0000E+00    F =  -0.3719E+02      0.0000E+00
     F
      232        13    F =   0.0000E+00    F =  -0.3719E+02      0.0000E+00
     F
      231        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      231        11    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      231        12    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      231        13    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      228        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
```

```
F
 231        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 232        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 233        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 224         9    F =   0.0000E+00    F =  -0.2188E+01      0.0000E+00
F
 225         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 226         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 227         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 228         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 229         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 230         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 231         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 232         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 233         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 234         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 235         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 236         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F

* * * * * COMPLETED MESH GENERATION  * * * * *

New Level 2 arch mesh

CALCULATED KEY NUMBERS ...
  THE NUMBER OF DATA ERRORS IS-----------    0
  THE NUMBER OF SOIL MATERIALS IS--------    3
  THE NUMBER OF PIPE-TYPE GROUPS IS------    1
  THE NUMBER OF INTERFACE MATERIALS IS---   19
  BAND WIDTH ESTIMATE (MAX)--------------   88


* * * * MESH DATA HAS BEEN SAVED ON UNIT 14 * * * *


 BEAM-NODE SEQUENCE NUMBERS FOR EACH GROUP


    BEAM-ELEMENT GROUP NUMBER =    1

     BEAM-NODE       MESH-NODE      CONNECTED-GROUP-ELEMENTS
     SEQUENCE        NUMBER         FOREWARD-#     BACKWARD-#
         1             198              1              0
         2             194              2              1
         3             190              3              2
         4             167              4              3
```

5	164	5	4
6	161	6	5
7	158	7	6
8	138	8	7
9	136	9	8
10	134	10	9
11	132	11	10
12	130	12	11
13	128	13	12
14	118	14	13
15	115	15	14
16	109	16	15
17	103	17	16
18	97	18	17
19	91	19	18
20	80	0	19

```
MATERIAL DESCRIPTION FOR SOILS AND INTERFACE
(ALL DENSITY UNITS ARE pcf, ALL MODULUS UNITS ARE psi)

   PROPERTIES FOR MATERIAL  1   ********in site

        DENSITY =    0.14000E+03

        YOUNGS MODULUS= 0.5000E+04
        POISSONS RATIO= 0.3500E+00
        CONFINED MOD.= 0.8025E+04
        LATERAL COEFF.= 0.5385E+00

   PROPERTIES FOR MATERIAL  2   ********Footing

        DENSITY =    0.15000E+03

        YOUNGS MODULUS= 0.3122E+07
        POISSONS RATIO= 0.1700E+00
        CONFINED MOD.= 0.3356E+07
        LATERAL COEFF.= 0.2048E+00

   PROPERTIES FOR MATERIAL  3   ********SW95

        DENSITY =    0.14000E+03

   CONTROLS FOR DUNCAN SOIL MODEL
   WITH SELIG HYPERBOLIC BULK MODULUS FORMULATION

         LRFD STRESS CONTROL..........        0

         ENTERING ELEMENT RATIO.......      0.5000


   HYPERBOLIC STRESS-STRAIN PARAMETERS


         SOIL CLASSIFICATION ............SW95
```

COHESION INTERCEPT C 0.0000

FRICTION ANGLE PHIO (DEG)..... 48.0000

10-FOLD REDUCTION IN PHIO(DEG).. 8.0000

SCALED MODULUS NUMBER ZK 950.0000

MODULUS EXPONENT ZN 0.6000

FAILURE RATIO RF 0.7000

INIT. BULK MODULUS NUMBER BI.... 74.8000

ULT. VOLUMETRIC STRAIN EU 0.0200

INTERFACE ELEMENT MATERIAL-GROUP PROPERTIES

MAT. NO.	NORMAL-ANGLE	COEF-FRICTION	TENSILE-RUPTURE	INITIAL-GAP
1	90.00	0.40000	10.00000	0.00000
2	88.11	0.40000	10.00000	0.00000
3	86.22	0.40000	10.00000	0.00000
4	84.32	0.40000	10.00000	0.00000
5	82.43	0.40000	10.00000	0.00000
6	80.54	0.40000	10.00000	0.00000
7	78.65	0.40000	10.00000	0.00000
8	76.76	0.40000	10.00000	0.00000
9	74.87	0.40000	10.00000	0.00000
10	72.97	0.40000	10.00000	0.00000
11	71.08	0.40000	10.00000	0.00000
12	69.19	0.40000	10.00000	0.00000
13	67.30	0.40000	10.00000	0.00000
14	65.41	0.40000	10.00000	0.00000
15	10.46	0.40000	10.00000	0.00000
16	5.11	0.40000	10.00000	0.00000
17	0.00	0.40000	10.00000	0.00000
18	0.00	0.40000	10.00000	0.00000
19	0.00	0.40000	10.00000	0.00000

LRFD TOTAL LOAD FACTORS PER LOAD STEP

LOAD STEP	LOAD FACTOR	USER COMMENT
1	1.310	Factor for load step #1
2	0.857	Factor for load step #2
3	0.857	Factor for load step #3
4	0.857	Factor for load step #4
5	1.365	Factor for load step #5
6	1.365	Factor for load step #6
7	1.365	Factor for load step #7

28x10_5Axle c1Mod.out

8	1.365	Factor for load step #8
9	1.500	Factor for load step #9
10	1.350	Factor for load step #10
11	1.350	Factor for load step #11
12	1.350	Factor for load step #12
13	1.350	Factor for load step #13

+

SOLUTION OUTPUT RESULTS

+

FINITE ELEMENT OUTPUT FOR LOAD STEP 13

+

CONCRETE, FACTORED-EVALUATION FOR GROUP 1, LOAD-STEP 13

STRUCTURAL RESPONSES OF CONCRETE-GROUP 1, LOAD-STEP 13
COORDINATES, DISPLACEMENTS AND CRACK DEPTHS ARE INCHES
Y-BAR IS "NEUTRAL AXIS" LOCATION FROM INTERIOR, INCHES
PRESSURES ARE LB/IN**2
MOMENTS ARE IN-LB/IN
THRUST AND SHEAR ARE LB/IN

LOCAL NODE	X-COORD. Y-COORD.	X-DISP. Y-DISP.	N-PRES. S-PRES.	MOMENT THRUST	Y-BAR CRACK DEPTH
1	0.00 125.00	0.00000E+00 -0.16070E+01	-0.20299E+02 0.31153E+01	0.33221E+05 -0.10455E+04	0.66148E+01 0.63173E+01
2	13.42 124.78	-0.27784E-03 -0.15920E+01	-0.16009E+02 -0.74175E+00	0.32060E+05 -0.10618E+04	0.66148E+01 0.63024E+01
3	26.80 124.11	0.13590E-02 -0.15483E+01	-0.11718E+02 -0.45988E+01	0.28337E+05 -0.11069E+04	0.66148E+01 0.62493E+01
4	40.15 123.01	0.65080E-02 -0.14793E+01	-0.75758E+01 -0.29530E+01	0.22846E+05 -0.11715E+04	0.66148E+01 0.61376E+01
5	53.46 121.47	0.16297E-01 -0.13900E+01	-0.39132E+01 -0.14933E+01	0.16356E+05 -0.12182E+04	0.65476E+01 0.59077E+01
6	66.71 119.48	0.31212E-01 -0.12867E+01	-0.17272E+01 -0.62848E+00	0.95498E+04 -0.12507E+04	0.65476E+01 0.54246E+01

7	79.89	0.51042E-01	-0.35577E+01	0.28324E+04	0.61238E+01
	117.06	-0.11760E+01	-0.13704E+01	-0.12829E+04	0.31506E+01
8	92.98	0.74994E-01	-0.38219E+01	-0.41114E+04	0.32912E+01
	114.21	-0.10644E+01	-0.14853E+01	-0.13217E+04	0.38023E+01
9	105.97	0.10180E+00	-0.57441E+01	-0.11308E+05	0.29481E+01
	110.92	-0.95653E+00	-0.22629E+01	-0.13676E+04	0.62731E+01
10	118.85	0.12891E+00	-0.82433E+01	-0.19085E+05	0.30809E+01
	107.21	-0.85997E+00	-0.32706E+01	-0.14275E+04	0.69545E+01
11	131.59	0.15362E+00	-0.88192E+01	-0.27872E+05	0.34674E+01
	103.08	-0.78150E+00	-0.14914E+01	-0.14854E+04	0.82564E+01
12	144.19	0.17500E+00	-0.11979E+02	-0.37772E+05	0.40809E+01
	98.53	-0.72046E+00	-0.40316E+01	-0.15527E+04	0.10341E+02
13	156.64	0.19333E+00	-0.10499E+02	-0.49361E+05	0.49117E+01
	93.56	-0.67298E+00	-0.26515E+01	-0.16336E+04	0.13319E+02
14	168.91	0.20957E+00	-0.11284E+02	-0.62400E+05	0.57315E+01
	88.19	-0.63464E+00	-0.74759E+01	-0.18148E+04	0.19305E+02
15	171.76	0.24105E+00	-0.75412E+01	-0.54041E+05	0.47460E+01
	75.95	-0.62674E+00	-0.25175E+01	-0.19520E+04	0.12698E+02
16	173.47	0.26307E+00	-0.88416E+01	-0.44640E+05	0.37441E+01
	63.50	-0.62303E+00	-0.26584E+01	-0.19332E+04	0.92502E+01
17	174.00	0.26798E+00	-0.96055E+01	-0.34369E+05	0.33970E+01
	50.94	-0.62201E+00	-0.56531E+00	-0.19162E+04	0.80427E+01
18	174.00	0.24385E+00	-0.61064E+01	-0.21540E+05	0.34814E+01
	33.96	-0.62086E+00	0.15168E+01	-0.19074E+04	0.75965E+01
19	174.00	0.19492E+00	-0.20721E+01	-0.10471E+05	0.36437E+01
	16.98	-0.61985E+00	0.50593E+00	-0.19079E+04	0.64781E+01
20	174.00	0.13624E+00	0.19622E+01	0.13256E-09	0.61687E+01
	0.00	-0.61919E+00	-0.50494E+00	-0.19170E+04	0.00000E+00

SHEAR FORCE DIAGNOSTCS FOR CONCRETE-GROUP 1, LOAD STEP 13
-- V-factor is coefficient of sqrt(PFPC) equal to capacity.
-- Shear depth "d" is negative if measured from outer wall.
-- Stirrup load is excess shear force above capacity.

NODE	EQUIVALENT V-factor	SHEAR CAPACITY lbs/inch	APPLIED SHEAR lbs/inch	APPLIED/ CAPACITY ratio	SHEAR DEPTH-d inches	STIRRUP LOAD lbs/inch
1	2.73	1763.00	-9.15	0.005	8.00	0.00
2	2.74	1764.36	182.17	0.103	8.00	0.00
3	2.74	1768.14	343.85	0.194	8.00	0.00
4	2.75	1773.55	447.08	0.252	8.00	0.00
5	2.76	1777.46	496.15	0.279	8.00	0.00
6	3.61	2330.44	504.68	0.217	8.00	0.00
7	4.50	2923.16	509.79	0.174	8.06	0.00
8	4.50	2764.55	527.68	0.191	-7.63	0.00
9	3.16	1942.58	558.77	0.288	-7.63	0.00

10	2.45	1617.60	618.13	0.382	-8.19	0.00
11	2.16	1718.07	697.35	0.406	-9.88	0.00
12	1.86	1905.49	801.87	0.421	-12.69	0.00
13	1.63	2198.06	919.05	0.418	-16.69	0.00
14	1.43	2826.80	153.81	0.054	-24.56	0.00
15	1.68	2155.54	-706.70	0.328	-15.88	0.00
16	2.03	1824.99	-782.38	0.429	-11.13	0.00
17	2.24	1727.93	-786.25	0.455	-9.56	0.00
18	2.32	1792.11	-703.73	0.393	-9.56	0.00
19	3.83	2949.04	-634.30	0.215	-9.56	0.00
20	4.50	3625.40	-599.12	0.165	10.00	0.00

STRESS AND STRAIN MEASURES FOR CONCRETE-GROUP 1, LOAD STEP 13

NODE	MAXIMUM COMPRESSION psi	AVERAGE SHEAR psi	RADIAL TENSION psi	INNER-WALL STRAIN in/in	OUTER-WALL STRAIN in/in
1	-2887.25	-1.18	11.43	0.1074E-02	-0.6101E-03
2	-2796.04	23.41	11.00	0.1034E-02	-0.5908E-03
3	-2500.67	44.19	9.65	0.9071E-03	-0.5284E-03
4	-2067.09	57.46	7.59	0.7200E-03	-0.4368E-03
5	-1544.97	63.76	5.16	0.4957E-03	-0.3265E-03
6	-983.93	64.86	2.69	0.2684E-03	-0.2079E-03
7	-362.80	64.99	0.20	0.3494E-04	-0.7667E-04
8	-392.78	67.27	0.00	-0.8300E-04	0.6648E-04
9	-1310.67	71.23	0.00	-0.2770E-03	0.4850E-03
10	-1852.34	73.53	0.00	-0.3914E-03	0.7706E-03
11	-1939.99	69.08	0.00	-0.4100E-03	0.8647E-03
12	-1745.28	62.13	0.00	-0.3688E-03	0.8289E-03
13	-1485.39	54.36	0.00	-0.3139E-03	0.7530E-03
14	-1051.34	6.21	0.00	-0.2222E-03	0.5924E-03
15	-1767.84	-43.91	0.00	-0.3736E-03	0.8774E-03
16	-2527.99	-68.97	0.00	-0.5342E-03	0.1177E-02
17	-2527.18	-80.38	0.00	-0.5340E-03	0.1116E-02
18	-1768.84	-71.95	0.00	-0.3738E-03	0.6721E-03
19	-962.28	-64.85	0.00	-0.2033E-03	0.2603E-03
20	-143.63	-61.25	0.00	-0.3035E-04	-0.3035E-04

STEEL STRESS AND CRACK WIDTHS FOR CONCRETE-GROUP 1, LOAD STEP 13
NOTE: CRACK WIDTH IS REDUCED TO SERVICE-LOAD LEVEL.
ALL OTHER RESPONSES ARE AT FACTORED LOAD LEVEL.

NODE	INNER CAGE psi	OUTER CAGE psi	MAX STRESS TO YIELD ratio	CRACK WIDTH inches
1	23486.30	-6363.31	0.3914	0.00406
2	22598.55	-6206.71	0.3766	0.00371
3	19758.94	-5688.86	0.3293	0.00260
4	15572.60	-4934.20	0.2595	0.00097
5	10557.83	-4017.33	0.1760	0.00000
6	5516.57	-2926.35	0.0919	0.00000
7	406.70	-1581.67	0.0264	0.00000
8	-1698.29	964.74	0.0283	0.00000
9	-4000.36	9573.94	0.1596	0.00000
10	-5503.49	16061.77	0.2677	0.00000
11	-6466.22	19515.62	0.3253	0.00000

12	-6706.17	20263.52	0.3377	0.00000
13	-6447.48	19663.18	0.3277	0.00000
14	-5157.03	16535.96	0.2756	0.00000
15	-7551.11	22655.54	0.3776	0.00000
16	-8981.72	27713.76	0.4619	0.00193
17	-8256.51	24875.30	0.4146	0.00160
18	-6356.87	14647.60	0.2441	0.00000
19	-4017.69	5293.75	0.0882	0.00000
20	-967.26	-967.26	0.0161	0.00000

ASSESSMENT SUMMARY CONCRETE-GROUP 1, LOAD-STEP 13

LRFD SUMMARY EVALUATION FOR GROUP 1, LOAD STEP 13

DESIGN-CRITERION	CONTROL NODE	FACTORED DEMAND	FACTORED CAPACITY	RATIO VALUE
STEEL YIELDING (psi)	16	27713.8	60000.0	0.462
CONCRETE CRUSHING (psi)	1	2887.3	4875.0	0.592
SHEAR FAILURE (lbs/in)	17	786.2	1555.1	0.506
RADIAL-TENSION FAIL (psi)	1	11.4	69.6	0.164

LRFD SERVICE-LOAD PERFORMANCE MEASURES FOR GROUP 1, LOAD STEP 13

NODE NUMBER FOR MAXIMUM CRACK WIDTH 1

MAXIMUM CRACK WIDTH AT SERVICE LOAD (inches) 0.00406

LRFD RATIO: MAX-CRACK-WIDTH / ALLOWABLE 0.41

SPAN LENGTH FOR AUXILIARY EQUATIONS (inches)..... 348.00

* * * * NORMAL EXIT FROM CANDE * * * *

28x10_5Axlec2Mod.out

```
*** WELCOME TO CANDE-2013(version 3/1/2013) ***

MASTER CONTROL AND PIPE-TYPE DATA FOR PROBLEM #  1

        USER TITLE: 28x10

        EXECUTION MODE ..................   ANALYS

        SOLUTION LEVEL ..................  #2 AUTO

        METHODOLOGY (LRFD OR SERVICE) ...     LRFD

        NUMBER OF PIPE-ELEMENT GROUPS ....       1

        MAXIMUM ITERATIONS PER STEP ......      30


        CULVERT PIPE-TYPE ............... CONCRETE

        CANNED MESH CODE # ..............        3

        NUMBER OF BEAM ELEMENTS .........       19

        CONCRETE MATERIAL PROPERTIES ARE AS FOLLOWS

             COMPRESSION STRENGTH (psi)..........       6500.000

             ELASTIC YOUNGS MODULUS (psi)........    4595487.000

             POISSON RATIO ......................          0.170

             CONCRETE DENSITY (pcf) .............        150.000

             INITIAL TENSILE CRACKING STRAIN.....       0.000010

             INITIAL COMPRESSION YIELD STRAIN....       0.000687

             INITIAL COMPRESSION CRUSH STRAIN ...       0.002000

             SHEAR STRENGTH MODEL (NSHEAR) # ...          1
             (VARIABLE STRENGTH MODEL PRINTED IN OUTPUT)

             CONCRETE CRACK-WIDTH MODEL NAME.....   HEGER-McGRATH
             (DRIVEN BY TENSILE STRAIN IN STEEL)

        STEEL REINFORCEMENT MATERIAL PROPERTIES

             TYPE OF STEEL CAGES (RSHAPE) .......     ARBIT

             STEEL YIELD STRENGTH (psi)..........      60000.000

             STEEL ELASTIC MODULUS (psi).........   29000000.000
```

28x10_5Axlec2Mod.out

STEEL POISSON RATIO 0.300000

STEEL YIELDING STRAIN 0.001883

NONLINEAR MODELING CODE (1,2,3) 3

STEEL-BASED CRACKWIDTH PREDICTION PARAMETERS

REBAR SPACING INNER ROW (SLI), (in)	4.00
REBAR SPACING OUTER ROW (SLO), (in)	4.00
NUMBER OF STEEL LAYERS FOR INNER CAGE	1
NUMBER OF STEEL LAYERS FOR OUTER CAGE	1
HEGER-MCGRATH CODE NUMBER FOR STEEL TYPE..	3

WALL THICKNESS, REBAR AREAS AND COVER DEPTHS

WALL-THICK	INNER-REBAR	OUTER-REBAR	INNER-COVER	OUTER COVER
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0000	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1980	0.0750	2.0000	2.4375
10.0630	0.1100	0.1500	2.0000	2.4375
10.6250	0.1100	0.1500	2.0000	2.4375
12.3130	0.1100	0.1500	2.0000	2.4375
15.1250	0.1100	0.1500	2.0000	2.4375
19.1250	0.1100	0.1500	2.0000	2.4375
27.0000	0.1100	0.1500	2.0000	2.4375
18.3130	0.1100	0.1500	2.0000	2.4375
13.5630	0.1100	0.1500	2.0000	2.4375
12.0000	0.1100	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375
12.0000	0.0500	0.1500	2.0000	2.4375

LRFD RESISTANCE FACTORS FOR STRENGTH-LIMIT STATES
AND CRACK-WIDTH LIMIT AT SERVICE LOAD

YIELDING OF REINFORCEMENT STEEL	1.000
CRUSHING OF CONCRETE OUTER FIBER.....	0.750
SHEARING FAILURE OF CONCRETE	0.900
SPLITTING OF CONCRETE IN RADIAL TENSION	0.900
ALLOWABLE CRACKWIDTH SERVICE LOAD (inch)....	0.010

LARGE DEFORMATION/BUCKLING CODE, IBUCK = 0
IBUCK=0, MEANS SMALL DEFORMATION THEORY FOR GROUP
AND NO BUCKLING PREDICTION.

28x10_5Axlec2Mod.out

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


 REVIEW SYSTEM INPUT DATA


 LEVEL-2 DATA FOR ARCH-TYPE CANNED MESH


    *** MESH PARAMETERS ***
     TYPE OF MESH ------------------------------------- TREN
     DEPTH OF TRENCH ABOVE FOOTING LEVEL (FT) ---------   12.42
     WIDTH OF TRENCH AT FOOTING LEVEL (FT) ------------    5.00
     SLOPE OF TRENCH WALL (H/V) -----------------------    0.00
     MESH SPACING PARAMETER ---------------------------    1.00
     TOTAL SOIL HEIGHT ABOVE CROWN (FT) ---------------    2.00
     MESH HEIGHT ABOVE CROWN (FT) ----------------------    2.00
     SOIL DENSITY ABOVE MESH (PCF) --------------------  140.00
     NUMBER OF ELEMENT LAYERS ABOVE CROWN -------------    3


*** ARCH PARAMETERS ***
     CENTERLINE RISE OF ARCH (IN) ----------------------  125.00
     BOTTOM HALF SPAN OF ARCH (IN) ---------------------  174.00
     SIDE RISE OF ARCH ABOVE FOOTING (IN) -------------   50.94
     FOOTING DEPTH (IN) --------------------------------   24.00
     OUTSIDE FOOTING WIDTH (IN) ------------------------   30.00
     INSIDE FOOTING WIDTH (IN) -------------------------   30.00
     NUMBER OF ARCH SEGMENTS DEFINED -------------------    3

*** CURVED TOP SEGMENT ***
     RADIUS (IN) ---------------------------------------  405.88
     CENTRAL ANGLE (DEG) -------------------------------   24.59
     SEGMENT ARC LENGTH (IN) ---------------------------  174.19
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------   13

*** CURVED CORNER SEGMENT ***
     RADIUS (IN) ---------------------------------------  133.94
     CENTRAL ANGLE (DEG) -------------------------------   16.14
     SEGMENT ARC LENGTH (IN) ---------------------------   37.73
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

*** STRAIGHT SIDE SEGMENT ***
     DEFLECTION ANGLE (DEG) ----------------------------   90.00
     SEGMENT LENGTH (IN) -------------------------------   50.94
     NUMBER OF BEAM ELEMENTS IN SEGMENT ----------------    3

 FINITE ELEMENT INPUT CONTROLS (PREP)


THE DATA TO BE RUN IS ENTITLED ...

New Level 2 arch mesh

PRINT AND PLOT CONTROL CODES ...
  PRINT CONTROL FOR MESH DATA------------    1
  PLOT FILE CONTROL MESH & RESULS--------    3
  PRINT FINITE ELEMENT RESULTS ----------    1
  INPUT DATA CHECK CODE------------------    0
```

28x10_5Axlec2Mod.out

```
KEY NUMBERS DESCRIBING MESH ...
  THE NUMBER OF LOAD STEPS IS------------   13
  TOTAL NUMBER OF NODES IS---------------  244
  TOTAL NUMBER OF ELEMENTS IS------------  209
  TOTAL NUMBER OF BEAM ELEMENTS IS-------   19
  MAX NUMBER OF BOUNDARY CONDITIONS IS---   36



 EXTENDED LEVEL-2: CHANGES TO CANNED MESH

          * NUMBER OF NODES TO BE CHANGED -------      0 *
          * NUMBER OF ELEMENTS TO BE CHANGED ----      0 *
          * ADDITIONAL BOUNDARY CONDITIONS ------     31 *



* * * BOUNDARY CONDITIONS * * *
 (FORCES = LBS; DISPLACEMENTS = INCHES; ROTATIONS = DEGREES)

 BOUNDARY      LOAD      X-FORCE     OR      Y-FORCE     OR      X-Y ROTATION
BEAM ROTATIONAL
     NODE      STEP      X-DISPLACEMENT      Y-DISPLACEMENT
BOUNDARY CONDITIONS

      228        10    F =   0.0000E+00    F =  -0.7903E+02      0.0000E+00
     F
      228        11    F =   0.0000E+00    F =  -0.7903E+02      0.0000E+00
     F
      228        12    F =   0.0000E+00    F =  -0.7903E+02      0.0000E+00
     F
      228        13    F =   0.0000E+00    F =  -0.7903E+02      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =  -0.7903E+02      0.0000E+00
     F
      230        11    F =   0.0000E+00    F =  -0.7903E+02      0.0000E+00
     F
      230        12    F =   0.0000E+00    F =  -0.7903E+02      0.0000E+00
     F
      230        13    F =   0.0000E+00    F =  -0.7903E+02      0.0000E+00
     F
      231        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      231        11    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      231        12    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      231        13    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      228        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      229        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
     F
      230        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
```

```
F
 231        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 232        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 233        10    F =   0.0000E+00    F =   0.0000E+00      0.0000E+00
F
 224         9    F =   0.0000E+00    F =  -0.2188E+01      0.0000E+00
F
 225         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 226         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 227         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 228         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 229         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 230         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 231         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 232         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 233         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 234         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 235         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F
 236         9    F =   0.0000E+00    F =  -0.4375E+01      0.0000E+00
F

* * * * * COMPLETED MESH GENERATION  * * * * *

New Level 2 arch mesh

CALCULATED KEY NUMBERS ...
  THE NUMBER OF DATA ERRORS IS-----------    0
  THE NUMBER OF SOIL MATERIALS IS--------    3
  THE NUMBER OF PIPE-TYPE GROUPS IS------    1
  THE NUMBER OF INTERFACE MATERIALS IS---   19
  BAND WIDTH ESTIMATE (MAX)--------------   88


* * * * MESH DATA HAS BEEN SAVED ON UNIT 14 * * * *


 BEAM-NODE SEQUENCE NUMBERS FOR EACH GROUP


    BEAM-ELEMENT GROUP NUMBER =    1

     BEAM-NODE       MESH-NODE      CONNECTED-GROUP-ELEMENTS
     SEQUENCE        NUMBER         FOREWARD-#     BACKWARD-#
         1             198              1              0
         2             194              2              1
         3             190              3              2
         4             167              4              3
```

5	164	5	4
6	161	6	5
7	158	7	6
8	138	8	7
9	136	9	8
10	134	10	9
11	132	11	10
12	130	12	11
13	128	13	12
14	118	14	13
15	115	15	14
16	109	16	15
17	103	17	16
18	97	18	17
19	91	19	18
20	80	0	19

```
MATERIAL DESCRIPTION FOR SOILS AND INTERFACE
(ALL DENSITY UNITS ARE pcf, ALL MODULUS UNITS ARE psi)

   PROPERTIES FOR MATERIAL  1   ********in site

        DENSITY =    0.14000E+03

        YOUNGS MODULUS= 0.5000E+04
        POISSONS RATIO= 0.3500E+00
        CONFINED MOD.= 0.8025E+04
        LATERAL COEFF.= 0.5385E+00

   PROPERTIES FOR MATERIAL  2   ********Footing

        DENSITY =    0.15000E+03

        YOUNGS MODULUS= 0.3122E+07
        POISSONS RATIO= 0.1700E+00
        CONFINED MOD.= 0.3356E+07
        LATERAL COEFF.= 0.2048E+00

   PROPERTIES FOR MATERIAL  3   ********SW95

        DENSITY =    0.14000E+03

   CONTROLS FOR DUNCAN SOIL MODEL
   WITH SELIG HYPERBOLIC BULK MODULUS FORMULATION

         LRFD STRESS CONTROL..........        0

         ENTERING ELEMENT RATIO.......      0.5000


   HYPERBOLIC STRESS-STRAIN PARAMETERS


         SOIL CLASSIFICATION .............SW95
```

28x10_5Axlec2Mod.out

COHESION INTERCEPT C	0.0000
FRICTION ANGLE PHIO (DEG).....	48.0000
10-FOLD REDUCTION IN PHIO(DEG)..	8.0000
SCALED MODULUS NUMBER ZK	950.0000
MODULUS EXPONENT ZN	0.6000
FAILURE RATIO RF	0.7000
INIT. BULK MODULUS NUMBER BI....	74.8000
ULT. VOLUMETRIC STRAIN EU	0.0200

INTERFACE ELEMENT MATERIAL-GROUP PROPERTIES

MAT. NO.	NORMAL-ANGLE	COEF-FRICTION	TENSILE-RUPTURE	INITIAL-GAP
1	90.00	0.40000	10.00000	0.00000
2	88.11	0.40000	10.00000	0.00000
3	86.22	0.40000	10.00000	0.00000
4	84.32	0.40000	10.00000	0.00000
5	82.43	0.40000	10.00000	0.00000
6	80.54	0.40000	10.00000	0.00000
7	78.65	0.40000	10.00000	0.00000
8	76.76	0.40000	10.00000	0.00000
9	74.87	0.40000	10.00000	0.00000
10	72.97	0.40000	10.00000	0.00000
11	71.08	0.40000	10.00000	0.00000
12	69.19	0.40000	10.00000	0.00000
13	67.30	0.40000	10.00000	0.00000
14	65.41	0.40000	10.00000	0.00000
15	10.46	0.40000	10.00000	0.00000
16	5.11	0.40000	10.00000	0.00000
17	0.00	0.40000	10.00000	0.00000
18	0.00	0.40000	10.00000	0.00000
19	0.00	0.40000	10.00000	0.00000

LRFD TOTAL LOAD FACTORS PER LOAD STEP

LOAD STEP	LOAD FACTOR	USER COMMENT
1	1.310	Factor for load step #1
2	0.857	Factor for load step #2
3	0.857	Factor for load step #3
4	0.857	Factor for load step #4
5	1.365	Factor for load step #5
6	1.365	Factor for load step #6
7	1.365	Factor for load step #7

8	1.365	Factor for load step #8
9	1.500	Factor for load step #9
10	1.350	Factor for load step #10
11	1.350	Factor for load step #11
12	1.350	Factor for load step #12
13	1.350	Factor for load step #13

+ +

SOLUTION OUTPUT RESULTS

+ +

FINITE ELEMENT OUTPUT FOR LOAD STEP 13

+ +

CONCRETE, FACTORED-EVALUATION FOR GROUP 1, LOAD-STEP 13

STRUCTURAL RESPONSES OF CONCRETE-GROUP 1, LOAD-STEP 13
COORDINATES, DISPLACEMENTS AND CRACK DEPTHS ARE INCHES
Y-BAR IS "NEUTRAL AXIS" LOCATION FROM INTERIOR, INCHES
PRESSURES ARE LB/IN**2
MOMENTS ARE IN-LB/IN
THRUST AND SHEAR ARE LB/IN

LOCAL NODE	X-COORD. Y-COORD.	X-DISP. Y-DISP.	N-PRES. S-PRES.	MOMENT THRUST	Y-BAR CRACK DEPTH
1	0.00	0.00000E+00	-0.30411E+01	0.20424E+05	0.66148E+01
	125.00	-0.15603E+01	-0.42283E+00	-0.12124E+04	0.60680E+01
2	13.42	-0.45602E-03	-0.29599E+01	0.20332E+05	0.66148E+01
	124.78	-0.15510E+01	-0.31480E+00	-0.12174E+04	0.60632E+01
3	26.80	0.31134E-03	-0.28786E+01	0.20090E+05	0.66148E+01
	124.11	-0.15233E+01	-0.20677E+00	-0.12221E+04	0.60550E+01
4	40.15	0.35092E-02	-0.49653E+01	0.19716E+05	0.66148E+01
	123.01	-0.14775E+01	0.64775E+00	-0.12212E+04	0.60437E+01
5	53.46	0.10294E-01	-0.96803E+01	0.18837E+05	0.65476E+01
	121.47	-0.14141E+01	0.12022E+01	-0.12129E+04	0.59942E+01
6	66.71	0.21675E-01	-0.12764E+02	0.16601E+05	0.65476E+01
	119.48	-0.13345E+01	-0.79951E+00	-0.12177E+04	0.59184E+01

7	79.89	0.38261E-01	-0.14643E+02	0.12459E+05	0.65930E+01
	117.06	-0.12414E+01	-0.31778E+01	-0.12569E+04	0.56855E+01
8	92.98	0.59952E-01	-0.17466E+02	0.60887E+04	0.63124E+01
	114.21	-0.11400E+01	-0.69388E+01	-0.13432E+04	0.41849E+01
9	105.97	0.85907E-01	-0.11015E+02	-0.29752E+04	0.34272E+01
	110.92	-0.10354E+01	-0.40288E+01	-0.14411E+04	0.45239E+01
10	118.85	0.11414E+00	-0.14808E+02	-0.13532E+05	0.30809E+01
	107.21	-0.93489E+00	-0.58955E+01	-0.15375E+04	0.66585E+01
11	131.59	0.14172E+00	-0.70247E+01	-0.26231E+05	0.34674E+01
	103.08	-0.84736E+00	-0.27921E+01	-0.16303E+04	0.81684E+01
12	144.19	0.16670E+00	-0.78813E+01	-0.39655E+05	0.40809E+01
	98.53	-0.77613E+00	-0.31444E+01	-0.17088E+04	0.10319E+02
13	156.64	0.18879E+00	-0.86650E+01	-0.53964E+05	0.49117E+01
	93.56	-0.71909E+00	-0.34763E+01	-0.17963E+04	0.13330E+02
14	168.91	0.20877E+00	-0.10113E+02	-0.69321E+05	0.57315E+01
	88.19	-0.67208E+00	-0.81158E+01	-0.20212E+04	0.19338E+02
15	171.76	0.24815E+00	-0.74480E+01	-0.60321E+05	0.47460E+01
	75.95	-0.66226E+00	-0.24839E+01	-0.21903E+04	0.12709E+02
16	173.47	0.27706E+00	-0.91557E+01	-0.49985E+05	0.37441E+01
	63.50	-0.65751E+00	-0.27680E+01	-0.21652E+04	0.92585E+01
17	174.00	0.28684E+00	-0.10333E+02	-0.38556E+05	0.33970E+01
	50.94	-0.65620E+00	-0.69306E+00	-0.21440E+04	0.80519E+01
18	174.00	0.26556E+00	-0.68144E+01	-0.24182E+05	0.34814E+01
	33.96	-0.65490E+00	0.16165E+01	-0.21334E+04	0.76118E+01
19	174.00	0.21638E+00	-0.22138E+01	-0.11772E+05	0.36437E+01
	16.98	-0.65376E+00	0.56253E+00	-0.21325E+04	0.65268E+01
20	174.00	0.15622E+00	0.23868E+01	0.17985E-09	0.61687E+01
	0.00	-0.65303E+00	-0.49144E+00	-0.21407E+04	0.00000E+00

SHEAR FORCE DIAGNOSTCS FOR CONCRETE-GROUP 1, LOAD STEP 13
-- V-factor is coefficient of sqrt(PFPC) equal to capacity.
-- Shear depth "d" is negative if measured from outer wall.
-- Stirrup load is excess shear force above capacity.

NODE	EQUIVALENT V-factor	SHEAR CAPACITY lbs/inch	APPLIED SHEAR lbs/inch	APPLIED/ CAPACITY ratio	SHEAR DEPTH-d inches	STIRRUP LOAD lbs/inch
1	2.76	1776.98	1.27	0.001	8.00	0.00
2	2.76	1777.40	12.47	0.007	8.00	0.00
3	2.76	1777.79	22.96	0.013	8.00	0.00
4	2.76	1777.72	46.75	0.026	8.00	0.00
5	2.76	1777.02	116.24	0.065	8.00	0.00
6	2.76	1777.43	237.99	0.134	8.00	0.00
7	2.74	1782.74	392.30	0.220	8.06	0.00
8	4.50	2923.16	575.96	0.197	8.06	0.00

9	4.50	2764.55	732.21	0.265	-7.63	0.00
10	3.73	2462.07	867.84	0.352	-8.19	0.00
11	2.47	1964.08	974.80	0.496	-9.88	0.00
12	1.94	1983.49	1034.88	0.522	-12.69	0.00
13	1.73	2321.61	1107.05	0.477	-16.69	0.00
14	1.43	2837.26	214.80	0.076	-24.56	0.00
15	1.69	2168.86	-769.36	0.355	-15.88	0.00
16	2.05	1839.56	-865.60	0.471	-11.13	0.00
17	2.26	1743.12	-877.84	0.504	-9.56	0.00
18	2.34	1804.93	-788.74	0.437	-9.56	0.00
19	3.85	2969.45	-712.09	0.240	-9.56	0.00
20	4.50	3625.40	-674.51	0.186	10.00	0.00

STRESS AND STRAIN MEASURES FOR CONCRETE-GROUP 1, LOAD STEP 13

NODE	MAXIMUM COMPRESSION psi	AVERAGE SHEAR psi	RADIAL TENSION psi	INNER-WALL STRAIN in/in	OUTER-WALL STRAIN in/in
1	-1878.28	0.16	6.68	0.6380E-03	-0.3969E-03
2	-1871.82	1.60	6.65	0.6346E-03	-0.3955E-03
3	-1851.79	2.95	6.58	0.6260E-03	-0.3913E-03
4	-1819.81	6.01	6.42	0.6127E-03	-0.3846E-03
5	-1748.52	14.94	6.05	0.5779E-03	-0.3695E-03
6	-1559.72	30.59	5.22	0.5024E-03	-0.3296E-03
7	-1161.84	50.01	3.49	0.3419E-03	-0.2455E-03
8	-564.46	73.42	0.90	0.1020E-03	-0.1193E-03
9	-564.46	93.34	0.00	-0.1088E-03	0.8883E-04
10	-1408.29	103.24	0.00	-0.2976E-03	0.5263E-03
11	-1863.48	96.57	0.00	-0.3938E-03	0.8058E-03
12	-1843.23	80.18	0.00	-0.3895E-03	0.8679E-03
13	-1625.09	65.48	0.00	-0.3434E-03	0.8229E-03
14	-1169.16	8.67	0.00	-0.2471E-03	0.6588E-03
15	-1974.65	-47.80	0.00	-0.4173E-03	0.9791E-03
16	-2830.81	-76.30	0.00	-0.5982E-03	0.1318E-02
17	-2834.13	-89.75	0.00	-0.5989E-03	0.1252E-02
18	-1984.96	-80.64	0.00	-0.4195E-03	0.7549E-03
19	-1083.84	-72.80	0.00	-0.2290E-03	0.2950E-03
20	-160.39	-68.96	0.00	-0.3389E-04	-0.3389E-04

STEEL STRESS AND CRACK WIDTHS FOR CONCRETE-GROUP 1, LOAD STEP 13
NOTE: CRACK WIDTH IS REDUCED TO SERVICE-LOAD LEVEL.
ALL OTHER RESPONSES ARE AT FACTORED LOAD LEVEL.

NODE	INNER CAGE psi	OUTER CAGE psi	MAX STRESS TO YIELD ratio	CRACK WIDTH inches
1	13734.46	-4610.17	0.2289	0.00024
2	13657.88	-4603.23	0.2276	0.00021
3	13464.33	-4568.40	0.2244	0.00014
4	13169.92	-4508.37	0.2195	0.00003
5	12377.10	-4416.13	0.2063	0.00000
6	10708.35	-4040.54	0.1785	0.00000
7	7174.28	-3290.00	0.1196	0.00000
8	1850.03	-2092.80	0.0349	0.00000
9	-2214.71	1305.61	0.0369	0.00000
10	-4541.18	10749.93	0.1792	0.00000

11	-6339.64	18111.87	0.3019	0.00000
12	-7114.23	21199.82	0.3533	0.00000
13	-7056.71	21488.55	0.3581	0.00000
14	-5734.99	18388.93	0.3065	0.00000
15	-8437.86	25278.91	0.4213	0.00000
16	-10057.83	31032.12	0.5172	0.00332
17	-9256.08	27912.24	0.4652	0.00287
18	-7129.62	16456.40	0.2743	0.00000
19	-4515.26	6010.15	0.1002	0.00000
20	-1080.09	-1080.09	0.0180	0.00000

ASSESSMENT SUMMARY CONCRETE-GROUP 1, LOAD-STEP 13

LRFD SUMMARY EVALUATION FOR GROUP 1, LOAD STEP 13

DESIGN-CRITERION	CONTROL NODE	FACTORED DEMAND	FACTORED CAPACITY	RATIO VALUE
STEEL YIELDING (psi)	16	31032.1	60000.0	0.517
CONCRETE CRUSHING (psi)	17	2834.1	4875.0	0.581
SHEAR FAILURE (lbs/in)	12	1034.9	1785.1	0.580
RADIAL-TENSION FAIL (psi)	1	6.7	69.6	0.096

LRFD SERVICE-LOAD PERFORMANCE MEASURES FOR GROUP 1, LOAD STEP 13

NODE NUMBER FOR MAXIMUM CRACK WIDTH 16

MAXIMUM CRACK WIDTH AT SERVICE LOAD (inches) 0.00332

LRFD RATIO: MAX-CRACK-WIDTH / ALLOWABLE 0.33

SPAN LENGTH FOR AUXILIARY EQUATIONS (inches)..... 348.00

* * * * NORMAL EXIT FROM CANDE * * * *