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The design of a reinforced concrete arch highway bridge

Clinton DeWitt Smith

MSM
HISTORICAL
COLLECTION

THE DESIGN OF A REINFORCED CONCRETE ARCH HIGHWAY BRIDGE.

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in
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Approved Elmo Harris April ___ 1915.

The Subject of this theses is the Design of a Reinforced Concrete Arch Highway Bridge .

In making the Design the crossing of South River Street, Austin Minn., was taken as the hypothetical location of the bridge and the design made with reference to the requirements of this location .

These requirements are no more than those for an ordinary rural highway bridge. While in the city of Austin it is not in the route of travel to and from the depots and is hence not subjected to the loads due to heavy freighting. There is however a heavy rural traffic, this road being one of the main arteries leading into the city.

The present bridge on this site is a Pratt truss of one hundred feet clear span. With the exception of one year this span has always provided an ample waterway. As the floods this year were the highest on record and resultant from a cloudburst in the near vicinity it was assumed for this design that this area for waterway is sufficient. In order to make up for the reduced head room resultant from the arch construction however the span decided upon was approximately one hundred and twenty one ft in the clear.

The rise adopted is seventeen and a half feet. This is a ratio of rise to span of about one to seven.

The foundation available is favorable for arch construction and consists of a limestone ledge. The thickness of this ledge was not determined, it not being feasable nor neccessary for the present purpose to make borings. Assuming it to be nothing but a thin ledge the allowable pressure according to the Minnesota State Highway Commissions specifications, is twenty five tons per square foot.

The method followed in making the design was that of Howe, as advanced in his text, Symetrical Masonry Arches. Unit loads were first considered, and with this data the loading so arranged as to give the maximum stresses at the sections considered. These were three in number- at the spring line, at a point between one fourth and one third the span, and at the crown. These three sections according to Howe are those highest stressed.

SPECIFICATIONS.

Loadings-

Definition- The dead load includes the weight of the structure , floor and filling, using the following unit weights;-

Earth filling - - - - 100 lb. per cu. ft.

Concrete - - - - - - - 140 Lb. per cu. ft.

The live load is to be one hundred pounds per square foot surface of roadway and sidewalk, and so applied to give the maximum resultant stresses, or a fifteen ton traction engine with axels at ten ft. centers and six ft. gage, two thirds of the load being carried on the rear wheels. The load giving the maximum stresses to be used.

Stresses,-

All parts of the structure shall be proportioned so that the sum of the maximum stresses shall not exceed the following amounts in pounds per square inch. Stresses induced by a temperature range of 80 degrees shall be provided for.

Steel in shear - - 10,000 lb. per sq. in.

Concrete in shear- - 50 lb per square in.

Steel in tension - - 16,000 lb. per sq.in.

Steel in tension, temp. included, 20.000 lb.

Concrete in tension - - - 0

Maximum allowable stress in extreme fibres of the section, tho steel will carry all tension- - - - - - - - - - 750 lb. per sq. in.

Concrete in compression- - 600 lb. per " " .

With temperature included- 750 lb. " " .

Steel in compression, I5 times surrounding concrete.

Classes of concrete-

The following classes of concrete shall be used

Arch ring,- I - 2 - 4 - concrete.

Spandrel wall - - I - 2½ - 5 concrete.

Abutments and peirs to spring line I - 3 - 6.

Hand rails , including all concrete placed above spandrels - I - 2 - 3.

Expansion joints- shall be leftin spandrel walls, handrails ect. and for over thirty foot span must be five or more in number.

Drainage - Shall be provided for the back of the arch at each abutment by pipe drains.

Spandrel walls- preferably of the gravity type and free to move on the arch ring.

ESTIMATE.

CONCRETE-

Arch Ring - 635 cu yd. I - 2 - 4 concrete.

Spandrel walls II5 Cu. yd. I - 2½ - 5 Concret.

Abutments,- 739 cu.yd I - 3 - 6 concrete.

Total number yd. concrete 1489.

STEEL -

I554 ft. ¾" sq. rods	2973. lb.
I4002 ft. ½" sq. rods	II90I. lb.
I5340 ft. I¼ by I I/I6"	69330. lb.
448 ft. ½ by 2¼"	I7I6. lb.
Total no. lb. steel	85920.

Fill -

834 cu yd. fill at $I.25 - - $I040.

Sidewalk-

177 ft at 40 cents per ft. $ 7I

Pavement,-

I83 sq. yds. at $2.25 4I5

Estimated cost bridge at I3.00 $ I9300

Total $ 20826.

TABLE IX

Stress in extreme fibres in lb. per sq ft.

1	2	3	4	5	6	7
	Crown		Section seven		Section zero	
Loading	Top	Bottom	Top	Bottom	Top	Bottom
Dead load	-2318	+67484	+35089	+23350	+42742	+2466
Live load	-1974	+5990	+5273	-3254	-2371	+3536
" "	+3190	-732	-2470	+5183	+8110	-5983
Max Tension	-4292	0	0	0	0	-3517
Max Compress	+872	+73474	+40362	28533	50852	6002
Temp rise	40°F	40°F	40°F	40°F	40°F	40°F
" fall	40°F	40°F	40°F	40°F	40°F	40°F
Tension due to temp.	33100	46650	8350	20500	54200	49300
Comp. due to temp.	33100	46650	8350	20500	54200	49300
Max. tens. includ. temp.	37392	0	0	0	11458	52817
Max. comp. includ. temp.	33972	1,20,124	48712	49033	105,052	55302

Extra longitudinal reinforcem. for arch ring - flat bars 1/2" by 2 1/4" spaced at 12" and extending for distance of 8' each side of crown - placed in bottom of arch ring.

point	1	2	3	4	5	6	7	8	9	10	11	12		13		14		15	
	h	h^3	$h^3/12$	$h/2$	$h/2 - .17$		$.24d^2$	col. 3+7		ds/I_x						$\Delta(y - \frac{\Sigma y\Delta}{\Sigma\Delta})$			
			I_c		d	d^2	I_s	I_x	ds	Δ	y	$y\Delta$		$y - \frac{\Sigma y\Delta}{\Sigma\Delta}$		B		yB	
1	3.04	28.10	2.34	1.52	1.35	1.82	.44	2.78	4.80	1.80	1.96	3	53	-12	651	-22	772	-44	633
2	2.58	17.17	1.44	1.29	1.12	1.25	.30	1.74	7.76	4.46	6.07	27	07	-8	541	-38	093	-231	224
3	2.55	16.57	1.38	1.27	1.10	1.21	.29	1.67	6.95	4.16	9.00	37	44	-5	611	-23	342	-210	078
4	2.47	15.06	1.25	1.23	1.06	1.12	.27	1.52	6.75	4.44	11.4	50	62	-3	211	-14	257	-162	530
5	2.35	12.97	1.08	1.17	1.00	1.00	.24	1.32	6.68	5.06	13.4	67	80	-1	211	-6	128	-82	115
6	2.24	11.22	.93	1.12	.95	.90	.22	1.15	6.65	5.78	15.1	87	27	+	489	+2	826	+42	672
7	2.20	10.64	.89	1.10	.93	.86	.21	1.10	6.54	5.94	16.45	97	71	+1	839	+10	923	+179	683
8	2.12	9.52	.79	1.06	.89	.79	.19	.98	6.52	6.65	17.5	116	37	+2	889	+19	212	+336	210
9	2.09	8.99	.75	1.04	.87	.76	.18	.93	6.45	6.94	18.25	126	65	+3	639	+25	255	+460	904
10	2.06	8.73	.73	1.03	.86	.74	.17	.90	6.45	7.16	18.78	134	46	+4	169	+29	850	+560	583
11.	2.00	8.00	.66	1.00	.83	.69	.16	.82	3.25	3.96	18.80	74	45	+4	189	+16	588	+311	854
										56.35 2 112.70 $\Sigma\Delta$		823 37 2 1646 74 $\Sigma y\Delta$				-104.592 +104.654 +.062 should be 0		-730.580 +1891.906 1161.326 2 ΣyB = 2322.652.	

Reinforcement assumed as .8 % area crown section.

$$I_x = I_c + n I_s = \frac{h^3}{12} + 15 \times .008 \times 2 (d^2)$$

$$= I_c + .24 d^2$$

$$\frac{\Sigma y\Delta}{\Sigma\Delta} = 14.611$$

TABLE I - Data & Constants.

Point	1	2	3	4	5	6	7	$\frac{col.7\,dx}{4\Sigma yB}$	9.	10	11	12	13	14	Point
	Z	ZB	$\sum_{a}^{a} zB$	K	$\sum_{0}^{a} B$	$K\sum_{0}^{a} B$	col. 3 − 6.	H	ZΔ	$\sum_{x=0}^{x=a} z\Delta$	$\sum_{a}^{1/2} \Delta$	$K\sum_{a}^{1/2} \Delta$	col 9 + 12	$\frac{col.13\,dx}{4\Sigma\Delta}$ D	
1	1	-22.772	-22.772	1	-22.772	-22.772	0	0	1.80	1.80	54.55	54.55	56.35	.805	1'
2	4	-152.372	-175.140	4	-60.865	-243.460	+68.320	.0474	17.84	19.64	50.09	200.36	220.00	3.143	2'
3	8	-186.736	-361.880	8	-84.207	-673.656	+311.776	.2162	33.28	52.92	45.93	367.44	420.36	6.005	3'
4	12	-171.084	-532.964	12	-98.464	-1181.568	+648.604	.4496	53.28	106.20	41.49	497.88	604.08	8.630	4'
5	16	-98.048	-631.012	16	-104.592	-1673.472	+1042.460	.7226	80.96	187.16	36.43	582.88	770.04	11.001	5'
6	20	+56.52	-574.492	20	-101.766	-2035.320	+1460.828	1.0129	115.60	302.76	30.65	613.00	915.76	13.086	6'
7	24	+262.152	-312.340	24	-90.843	-2171.592	+1859.252	1.2890	142.56	445.32	24.71	593.04	1038.36	14.836	7'
8	28	+537.936	+225.596	28	-71.631	-2005.668	+2231.264	1.5470	186.20	631.52	18.06	505.68	1137.20	16.247	8'
9	32	+808.160	+1033.756	32	-46.376	-1484.032	+2517.788	1.7450	222.08	853.60	11.12	355.84	1209.44	17.276	9'
10	36	+1074.600	+2108.356	36	-16.526	-594.936	+2703.292	1.8743	257.76	1111.36	3.96	142.56	1253.92	17.915	10'
11	39	+646.932	+2755.288	39	+.062	-2.418	+2757.706	1.9121	154.44	1265.80	0	0	1265.80	18.083	11'
		+3386.300 -631.012 +2755.288						10.817 2 21.634 ΣH.							

$dx = 6.44$

$\Sigma yB = 2322.652$

TABLE II
HORIZONTAL THRUSTS & D.

point.	1	2	3	4	5	6	7	8	9	10	11	12	13	14.
	$n-K$	K	$z-n$	z	$z(z-n)$	$z(z-n)\Delta$	$\sum_{x=0}^{x=a} z(z-n)\Delta$	$(n-K)\sum_{x=0}^{x=a}(z-n)z\Delta$	$(z-n)^2$	$(z-n)^2\Delta$	$-\sum_{x=a}^{x=\frac{1}{2}l}(z-n)^2\Delta$	$-K\sum_{x=a}^{x=\frac{1}{2}L}(z-n)^2\Delta$	Column 8 + 12	Col. 13 times .0000328 = E
1	39	1	-39	1	-39	$\overline{-70.2}$	$\overline{70.20}$	$\overline{2737.80}$	$\overline{1521}$	$\overline{2737.80}$	$\overline{21788.44}$	$\overline{21788.44}$	$\overline{24526.24}$	.8045
2	36	4	-36	4	-144	$\overline{-642.24}$	$\overline{712.44}$	$\overline{25647.84}$	$\overline{1296}$	$\overline{5780.16}$	$\overline{16008.28}$	$\overline{64033.12}$	$\overline{89680.96}$	2.9415
3	32	8	-32	8	-256	$\overline{-1064.96}$	$\overline{1777.40}$	$\overline{56876.80}$	$\overline{1024}$	$\overline{4259.84}$	$\overline{11748.44}$	$\overline{93987.52}$	93987.52	3.0828
4	28	12	-28	12	-336	$\overline{-1491.84}$	$\overline{3269.24}$	$\overline{91538.72}$	$\overline{784}$	$\overline{3480.96}$	$\overline{8267.48}$	$\overline{99209.76}$	190748.48	6.2565
5	24	16	-24	16	-384	$\overline{-1943.04}$	$\overline{5212.28}$	$\overline{125094.72}$	$\overline{576}$	$\overline{2914.56}$	$\overline{5352.92}$	$\overline{85646.72}$	210741.44	6.9123
6	20	20	-20	20	-400	$\overline{-2312.00}$	$\overline{7524.28}$	$\overline{150485.60}$	$\overline{400}$	$\overline{2312.00}$	$\overline{3040.92}$	$\overline{60818.40}$	211304.00	6.9308
7	16	24	-16	24	-384	$\overline{-2280.96}$	$\overline{9805.24}$	$\overline{156883.84}$	$\overline{256}$	$\overline{1520.64}$	$\overline{1520.28}$	$\overline{36486.72}$	193370.56	6.3426
8	12	28	-12	28	-336	$\overline{2234.40}$	$\overline{12039.64}$	$\overline{144475.68}$	$\overline{144}$	$\overline{957.60}$	$\overline{562.68}$	$\overline{15755.04}$	160230.72	5.2556
9	8	32	-8	32	-256	$\overline{1776.64}$	$\overline{13816.28}$	$\overline{110530.24}$	$\overline{64}$	$\overline{444.16}$	$\overline{118.52}$	$\overline{3792.64}$	114322.88	3.7498
10	4	36	-4	36	-144	$\overline{1031.04}$	$\overline{14847.32}$	$\overline{59389.28}$	-16	$\overline{114.56}$	$\overline{3.96}$	$\overline{142.56}$	59531.84	1.9526
11	1	39	-1	39	-39	$\overline{154.44}$	$\overline{15001.76}$	$\overline{15001.76}$	-1	$\overline{3.96}$	0	0	15001.76	.4921

$$E = \left\{ (n-K) \sum_{x=0}^{x=a} (z-n) z \Delta - K \sum_{x=a}^{x=\frac{L}{2}} (z-n)^2 \Delta \right\} \frac{dx}{-8 \sum_{0}^{L/2} (z-n)^2 \Delta}$$

Col 8 Col 12.

Table III - Term "E"

TABLE IV

VALUES OF V_1, V_2, M_1, M_2 & H PRODUCED BY UNIT LOADS.

point	1 C	2 D	3 E	4 M_1	5 M_2	6 $M_2 - M_1$	7 $\frac{M_2 - M_1}{span}$	8 R_1	9 Col 2+3 V_1	10 V_2	11 point	12 point
1	0	.805	.805	-1.610	0	+1.610	.0125	.9876	1.000	0	1'	22
2	.6925	3.143	2.941	-5.391	+.491	+5.882	.0457	.9503	.996	.004	2'	21
3	3.159	6.005	3.083	-5.929	+.237	+6.166	.0479	.8998	.9477	.0523	3'	20
4	6.569	8.630	6.256	-8.317	+4.195	+12.512	.0971	.8501	.9472	.0528	4'	19
5	10.557	11.001	6.912	-7.356	+6.468	+13.824	.1073	.7997	.9070	.0930	5'	18
6	14.800	13.086	6.931	-5.217	+8.645	+13.862	.1076	.7500	.8576	.1424	6'	17
7	18.832	14.836	6.343	-2.347	+10.339	+12.686	.1240	.7000	.8240	.1760	7'	16
8	22.602	16.247	5.256	+1.099	+11.611	+10.512	.0816	.6500	.7316	.2684	8'	15
9	25.509	17.276	3.750	+4.483	+11.983	+6.500	.0505	.6000	.6505	.3495	9'	14
10	27.381	17.915	1.952	+7.514	+11.418	+3.904	.0308	.5500	.5808	.4192	10'	13
11	27.934	18.083	.492	+9.359	+10.343	.984	.0076	.5125	.5201	.4799	11'	12
				M_2	M_1				V_2	V_1		

$C = H \frac{\Sigma y\Delta}{\Sigma \Delta} = 14.611H$

$M_1 = C - D - E$

$M_2 = C - D + E.$

$\Sigma M_1 = -36.167 + 98.185 = +62.018 = M_2$

$\Sigma V_1 \pm 11 = \Sigma V_2$

TABLE V

STRESS IN EXTREME FIBRES OF SECTION AT THE CROWN.

CONSIDERING UNIT LOAD AS OCCUPYING SUCCESSIVELY EACH OF THE DEVISIONS.

Point	1	2	3	4	5	6	7	8	9	Point
	$4.839H$	$-\frac{\Sigma m_x \Delta}{\Sigma \Delta}$	$m_x = K\frac{dx}{8}$	M_x	$\frac{M_x}{S} = .335M_x$	$N_x = H\cos\phi$	$\frac{N_x}{F_x}$	Stress. Top	Bottom.	
1	0	-.805	.805	0	0	0	0	0	0	1'
2	.229	-3.143	3.220	-.152	.0509	.0474	.0114	-.0395	+.0623	2'
3	1.046	-6.005	6.440	.611	.2046	.2162	.0520	-.1526	+.2566	3'
4	2.176	-8.630	9.66	1.146	.3839	.4496	.1080	-.2759	+.4919	4'
5	3.497	-11.001	12.88	1.618	.5420	.7226	.1737	-.3683	+.7157	5'
6	4.902	-13.086	16.10	1.888	.6325	1.0129	.2439	-.3886	+.8764	6'
7	6.237	-14.836	19.32	1.753	.5876	1.289	.3098	-.2778	+.8974	7'
8	7.486	-16.247	22.54	1.193	.3996	1.547	.372	-.0276	+.7716	8'
9	8.449	-17.276	25.76	.035	.0117	1.7459	.420	+.4317	+.4083	9'
10	9.068	-17.915	28.98	1.997	.6690	1.8743	.451	+1.120	-.1180	10'
11	9.252	-18.083	31.40	4.065	1.3618	1.912	.460	1.8218	-.9018	11'

$I_x = \frac{3.5^3}{12} + 15 \times 1.25 \times 3.5(1.58)^2 = 5.212$ $\quad P = \frac{N_x}{F_x} + \frac{M_x}{S}$ (top)

$\frac{1.75}{5.212} = \frac{1}{S} = .335$ $\quad F_x = 3.5 + .656 = 4.156$ $\quad P = \frac{N_x}{F_x} - \frac{M_x}{S}$ (bottom)

TABLE VI

STRESS IN EXTREME FIBRES SECT. # 7. PRODUCED BY UNITLOADS MOVING ACCROSS SPAN.

Point	1	2	3	4	5	6	7	8	9	10
	$-1.839H$	$-\frac{\Sigma m_x \Delta}{\Sigma \Delta}$	$-.4E$	$+m_x$	M_x	M_x/S .2783 M_x	N_x	N_x/F_x	Stress Top	Stress Bottom
1	0	-.805	-.322	+1.127	0	0	0	0	0	0
2	-.087	-3.143	-1.177	+4.508	+.101	+.0281	.045	+.0091	+.0372	-.019
3	-.398	-6.005	-1.233	+9.016	1.380	.3840	.202	+.0444	+.4284	-.3396
4	-.827	-8.630	-2.503	+13.524	1.564	.4353	.432	+.0951	+.5304	-.3402
5	-1.329	-11.001	-2.765	+18.032	2.937	.8174	.692	+.1523	+.9697	-.6651
6	-1.859	-13.086	-2.772	+22.540	4.823	1.3422	.968	+.2129	+1.5551	-1.1293
7	-2.370	-14.836	-2.537	+27.048	7.305	2.0330	1.233	+.2715	+2.3045	-1.7615
8	-2.845	-16.247	-2.102	+25.116	3.922	+1.0915	1.656	+.3645	+1.456	-.7270
9	-3.211	-17.276	-1.500	+23.184	1.192	+.3317	1.837	+.4040	+.7357	-.0723
10	-3.446	-17.915	-.781	+21.252	.890	-.2477	1.949	+.4285	+.1808	+.6762
11	-3.516	-18.083	-.197	+19.803	1.993	-.5546	1.974	+.4350	-.1296	+.9896
12	-3.516	-18.083	+.197	+18.837	2.565	-.7138	1.967	+.4325	-.2813	+1.1463
13	-3.446	-17.915	+.781	+17.388	3.192	-.8883	1.918	+.4215	-.4668	+1.3098
14	-3.216	-17.276	+1.500	+15.456	3.536	-.9841	1.780	+.3916	-.5925	+1.3757
15	-2.845	-16.247	+2.102	+13.523	3.466	-.9646	1.569	+.3451	-.6195	+1.3097
16	-2.370	-14.836	+2.537	+11.592	3.077	-.8563	1.299	+.286	-.5703	+1.1423
17	-1.859	-13.086	+2.772	+9.660	2.513	-.6994	1.022	+.225	-.4744	+.9244
18	-1.329	-11.001	+2.765	+7.728	1.837	-.5112	.787	+.1733	-.3379	+.6845
19	-.827	-8.630	+2.503	+5.796	1.158	-.3223	.443	+.0974	-.2249	+.4197
20	-.398	-6.005	+1.233	+3.864	1.306	-.3634	.213	+.0469	-.3165	+.4103
21	-.087	-3.143	+1.177	+1.932	.121	-.0337	.047	+.0103	-.0234	+.0440
22.	.0	-.805	+.322	+4.83	0	0	0	0	0	0

$$M_x = H\left\{\frac{\Sigma y\Delta}{\Sigma\Delta} - y\right\} - \frac{\Sigma m_x \Delta}{\Sigma \Delta} - \frac{n-z}{n}E + m_x. \quad m_x = \left\{\frac{2n-K}{2n}z - (z-K)\right\}^{z>K}\frac{dx}{4}$$

$$M_x = (14.611 - 16.45)H - \frac{\Sigma m_x\Delta}{\Sigma\Delta} - .4E + m_x \quad . \quad m_x = \left\{\frac{80-K}{80}24 - (24-K)\right\}^{24>K}1.61$$

$h = 3.89$ $\quad I_x = 6.99$ $\quad 1/s = .2783$ $\quad F_x = 3.89 + .656 = 4.546$

$N_x = V_1 \sin\phi + H_1 \cos\phi - \Sigma^{x>a} \sin\phi$ $\quad \sin\phi = 25.76/137.8 = .187$ $\quad \cos\phi = .982$

TABLE VII

Stress in extreme fibres produced by unit loads, moving accross the span. — Section-0.

Point.	1	2	3	4	5	6	7
	$\frac{M_x}{S}$ = .1256 M	$V_1 \sin\phi$ .816 V_1	$H \cos\phi$ .578H	N_x	N_x/F_x	Stress Top	Stress Bottom
1	−.2022	.816	0	.816	+.121	−.0812	+.3232
2	−.6771	.813	.087	.840	+.1245	−.5526	+.8016
3	−.6697	.773	.125	.898	+.1333	−.5364	+.8030
4	−1.0446	.772	.260	1.032	+.1532	−.8914	+1.1978
5	−.9239	.740	.418	1.158	+.1717	−.7522	+1.0956
6	−.6552	.700	.585	1.285	.1907	−.4645	+.8459
7	−.2948	.672	.745	1.417	.2100	−.0848	+.5048
8	+.1380	.596	.894	1.490	.2210	+.3590	+.0830
9	+.5631	.530	1.009	1.539	.2280	+.7911	−.3351
10	+.9437	.474	1.083	1.557	.2310	+1.1747	−.6927
11	+1.1755	.425	1.105	1.530	.2270	+1.4025	−.9485
12	+1.2991	.392	1.105	1.497	.2220	+1.5211	−1.0771
13	+1.4341	.342	1.083	1.425	.2116	+1.6457	−1.2225
14	+1.5050	.285	1.009	1.294	.1920	+1.6970	−1.3130
15	+1.4583	.219	.894	1.113	.1677	+1.6260	−1.2906
16	+1.2986	.144	.745	.889	.1318	+1.4304	−1.1668
17	+1.0858	.116	.585	.701	.1040	+1.1898	−.9818
18	+.8124	.076	.418	.484	.0718	+.8842	−.7406
19	+.5269	.043	.260	.303	.0450	+.5719	−.4819
20	+.0298	.043	.125	.168	.0250	+.0548	−.0048
21	+.0616	.003	.027	.030	.004	+.0656	−.0576
22	0	0	0	0	0	0	0

8

stress top fibre $= \frac{N_x}{F_x} + \frac{M_x}{S}$

bottom $= N_x/F_x - \frac{M_x}{S}$

$\phi = 54°41'$

$\sin\phi = .816 \quad \cos\phi\ .578$

$c/I = \frac{1}{S} = .1256$

$h = 6.09 \quad I_x = 24.20$

$F_x = 6.09 + 6.56 = 6.746$

TABLE VIII

Stress in extreme fibres produced by unit horizontal loads acting toward center of span.

Point.	1	2	3	4	5	6	7
	M_x	$1/S$	M_x/S	N_x	N_x/F_x	Stress Top	Bottom
0	14.611	.1256	1.835	.578	.086	+1.921	−1.749
7	1.839	.2783	.512	.982	.216	−.296	+.728
℄	4.389	.335	1.414	1	.2405	−1.173	1.655

$$M_1 = H \frac{\Sigma y \Delta}{\Sigma \Delta} \qquad M_x = \left(\frac{\Sigma y \Delta}{\Sigma \Delta} - y \right) H$$

For 1° Fah. $H_t = \dfrac{.000006(126.80)(1,500,000)(144)}{2322.65}$

$H_t = 705$

Stress per unit area for temp. range of ± 40° Fah.

crown — 705 x 1.173 x 40 = ± 33100 #□' upper fibres
705 x 1.655 x 40 = ± 46650 #□' lower fibres.

seren — 705 x .296 x 40 = ± 8350 #□' upper fibres
705 x .728 x 40 = ± 20500 #□' lower " .

zero — 705 x 1.921 x 40 = ± 54200 #□' upper fib.
705 x 1.749 x 40 = ± 49300 #□' lower "

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