



April 11, 2017

Blaine Sanchez
273.3511
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Re: SE-17-174_Aqua Arch Structural Analysis

Dear Mr. Sanchez:

Southeast Engineers, LLC (SE) has completed the structural analysis of the Aqua Arch concrete blocks in accordance with AASHTO and ACI standards. SE has determined that the blocks are capable of servicing the loads imposed by AASHTO H20, HS20, and HS-25 loading.

SE analyzed the blocks as unreinforced concrete arches supporting a uniform truck tire load with impact, as per AASHTO standards. The attached calculations reflect ASSHTO HS-25 loading, as this is the controlling load. SE has found that ASTM D 6684-04 specified minimum concrete strength (4000 psi) is adequate for this design. Additionally, SE has determined that the minimum gravel thickness beneath the 12" and 8" blocks are 4" and 3", respectively.

Please be advised that the subgrade soil and base preparation for the Aqua Arch blocks must be prepared in accordance with the geotechnical engineer's recommendations for adequate performance of the system.



Sincerely,
Southeast Engineers, LLC



Project

SE-17-174

Eng: AKT

Date: 4/11/2017

Calculation Sheet for:

AQUA ARCH CONCRETE BLOCK LOADING ANALYSIS

Checker: RL

Date: 4/11/2017

Contractor Doc. No.

Item No. 1 AASHTO HS-25

A AQUA ARCH SECTION PROPERTIES

- NEGLECT CURVED PORTIONS OF BLOCK FOR M.O.I CALCULATIONS

$$I = \frac{bh^3}{12}$$

h= 2.625 in

b= 1.00 in

$$A = hb$$

$$S = \frac{bh^2}{6}$$

- FOR 1" WIDE STRIP (b=1")

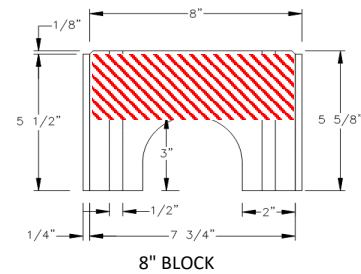
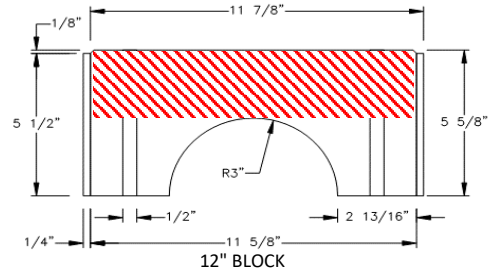
$$I = 1.51 \text{ in}^4$$

$$A = 2.63 \text{ in}^2$$

$$S = 1.15 \text{ in}^3$$

- CONCRETE COMPRESSIVE STRENGTH

$$F_c = 4000.00 \text{ PSI}$$



B HS-25 TRUCK LOADING (TIRE PRESSURE)

- TYPICAL PRESSURE = 100.00 PSI

- INCREASE FOR HEAT = 20.00 %

- INCREASE FOR IMPACT = 30.00 %

$$\omega = p(\phi_H)(\phi_I) = 156.00 \text{ PSI}$$

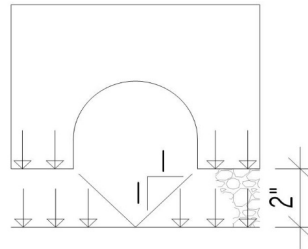
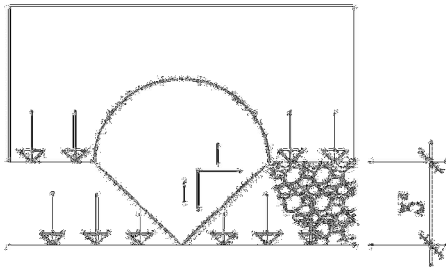
- FOR 1" STRIP $\omega = 156.00 \text{ LB/IN}$

C BEARING COMPRESSION CHECK

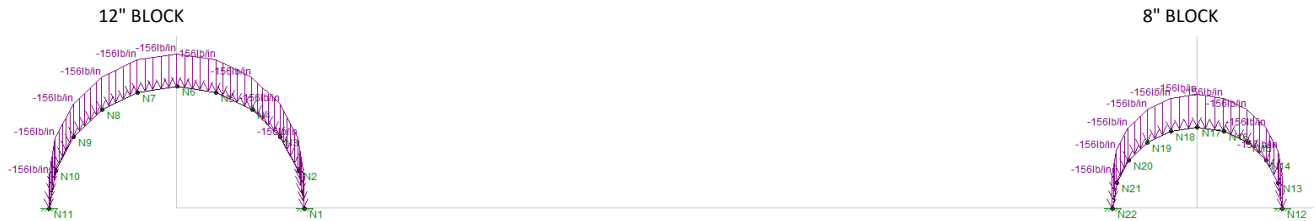
	12" BLOCK		8" BLOCK	
- BLOCK WIDTH (w) =	11.88	IN	8.00	IN
- BEARING WIDTH (wb) =	2.81	IN	2.00	IN
- HS25 WHEEL LOAD (Pw)=		40000.00		LB/ AXLE
$P = \frac{P_w}{2 \text{ SIDES}} (\phi_I)(\phi_{ULT}) = \frac{P_w}{2 \text{ SIDES}} (1.3)(1.7) =$		44200.00		LB
$F_{pu} = \frac{P}{A} =$	661.71	PSI	1381.25	PSI
$\phi F_p = (.7)(.85)F'_c =$		2380.00		PSI
- UTILIZATION FACTOR FOR EACH BLOCK TYPE	3.60	OK	1.72	OK

D SUBGRADE BEARING CHECK

- MINIMUM 3" GRAVEL BENEATH BLOCK TO ACHIEVE FULL BE SUBGRADE BEARING FOR 12" BLOCK.
- MINIMUM 2" GRAVEL BENEATH BLOCK TO ACHIEVE FULL SUBGRADE BEARING FOR 8" BLOCK.



D CHECK ARCH STRENGTH USING RISA 3D, USING IDEALIZED 1"x1" ARCH SECTION



- MEMBER FORCES SORTED BY MAXIMUM FOR BOTH BLOCKS RE: IMAGE (BELOW)

3D Maximum Member Section Forces (By Combination)														
Sections		Maximums		End Reactions										
LC	Member Label		Axial[lb]	Loc[ft]	y Shear[lb]	Loc[ft]	z Shear[lb]	Loc[ft]	Torque[lb-ft]	Loc[ft]	y-y Moment[lb-ft]	Loc[ft]	z-z Moment[lb-ft]	Loc[ft]
1	1	M9	max	377.37	.039	54.079	0	0	0	0	0	0	2.881	0
2			min	305.06	0	42.627	.039	0	0	0	0	0	.99	.039
3	1	M1	max	377.37	0	-42.627	0	0	0	0	0	0	2.881	.039
4			min	305.06	.039	-54.079	.039	0	0	0	0	0	.99	0
5	1	M2	max	306.84	0	42.85	0	0	0	0	0	0	2.881	0
6			min	241.608	.039	9.612	.039	0	0	0	0	0	1.855	.039
7	1	M8	max	306.84	.039	-9.612	0	0	0	0	0	0	2.881	.039
8			min	241.608	0	-42.85	.039	0	0	0	0	0	1.855	0
9	1	M19	max	249.706	.026	24.222	0	0	0	0	0	0	1.602	0
10			min	201.499	0	16.587	.026	0	0	0	0	0	1.07	.026

- FROM RISA MODEL, MAX COMPRESSION FORCE 378.00 LB

-ALLOWABLE COMPRESSION FORCE = $0.7(.85)F'_c =$ 2380.00 LB

- UTILIZATION RATIO FOR WORST CASE SCENARIO = 6.30 OK



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D CHECK RECTANGULAR SECTION ABOVE ARCH FOR MOMENT RESISTANCE AND ADEQUATE LOAD DISTRIBUTION

- MAXIMUM NOMINAL MOMENT FOR BEAM FIXED AT BOTH ENDS

$$M_{U(CENTER)} = \frac{\omega L^2}{24} = 234.00 \text{ LB-IN}$$

$$\phi M_N = \phi(\lambda)\sqrt{F_c'(S)} = 326.85 \text{ LB-IN}$$

- UTILIZATION RATIO FOR WORST CASE SCENARIO = 1.40 OK

NOTE: MOMENT RESISTANCE FOR 8" BLOCK IS OK BY COMPARISON, AS THE ULTIMATE MOMENT IS LESS