12/19/2024

8680-00-04
Superior
Bong Bridge B-16-38
Douglas County

B-16-38

Design Calculations

Prepared by

KL Engineering
[A] Better Experience

Madison, WI

Project: *USH 2 over St. Louis River*

Structure Number: *B-16-38* **Project #:** *22114*

Task: *Light Pole CIP Anchor Analysis - loading parallel to face of Parapet*

KL Engineering

Design By: *WAH* **Date:** *12/18/2024* **Checked By:** *SKH* **Date:** *12/19/2024*

CONCRETE MASONRY CIP ANCHOR DESIGN PROGRAM

DESIGN LOADS: Enter loads on single anchor or on group

Factored Tension Force, Nu =	11.03'-k *12"/' /10"	13.24	kips
Factored Shear Force, Vu =		0.59	kips

ANCHOR PROPERTIES:

Proposed Anchor Size =		1	inches
Analyze as Single Anchor or Group =	Group Analysis Required	Group	
If Group, # of Anchors Effective in Tension =	For force in rebar or bolt only (not concrete)	2	anchors
If Group, # of Anchors Effective in Shear =	For force in rebar or bolt only (not concrete)	6	anchors
Yield Strength of Anchor, fy =		55	ksi
Tensile Strength of Anchor, fut =		75	ksi
Condition of Concrete =			
Dry or Wet (Saturated) =		Saturated	
Cracked or Uncracked at Service Loads =		Cracked	
Compressive Strength =		4000	psi
Proposed Embedmen Depth =	OK, Below Limit of 20*Dia.	16	inches
Depth of Member =		19	inches

<u>Single Anchor Edge Distance & Spacing:</u> Note: See ACI 17.4.2.3 when located near 3 or more edges

Torqued or Not Torgued =		Not Torqued	
Minimum Edge Distance =		2	inches
Minimum Spacing =		4	inches
Left Side:			
Edge or Anchor =		Edge	
Distance to Edge or Anchor Spacing =	OK, Meets Minimum Edge Distance Requirement	6.125	inches
Right Side:			
Edge or Anchor =		Anchor	
Distance to Edge or Anchor Spacing =	OK, Meets Minimum Spacing Requirement	5.75	inches
Front:			
Edge or Anchor =		Edge	
Distance to Edge or Anchor Spacing =	OK, Meets Minimum Edge Distance Requirement	24	inches
Back:			
Edge or Anchor =		Edge	
Distance to Edge or Anchor Spacing =	OK, Meets Minimum Edge Distance Requirement	13	inches

ANCHOR GEOMETRIC PROPERTIES:

Determine Projected Concrete Breakout Area of a Single Anchor, A_Nc:

A_Nco = 9 * hef^2 =	2304.0	inches^2
S = min(1.5*hef, spacing/2, edge distance {ca})		
Left: S =	6.125	inches
Right: S =	2.875	inches
Front: S =	24	inches
Back: S =	13	inches
A_Nc =	333.0	inches^2

Calculate A_Nc per ACI Figure 17.4.2.1 for Anchor Group

1.5*hef =	24	inches
Width of Group =	18	inches
Depth of Group =	36	inches
A_Nc =	648	inches^2

Calculate A_vc per ACI Figure 17.5.2.1b for Anchor Group <u>override</u>

Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =	13.00	inches
1.5*Ca1 =	19.50	inches
Member Depth, ha =	19.00	inches
Width of Group =	18	inches
Depth of Group =	19.00	inches
A_vc =	342.0	inches^2

CIP ANCHOR TENSILE RESISTANCE:

Nominal Tensile Resistance, Nr = phi_ts*Nsa <= phi_tc*Ncb <= phi_tc*Na

Phi Factors:

Steel Classification =		Ductile		*ACI 2.3*
Supplementary Reinforcement Included =		Yes		*ACI 17.3.3*
phi_ts =		0.75		
phi_tc =		0.75		
phi_tc_pullout =		0.75		

Determine Nominal Steel Strength of Anchor in Tension, Nsa = Ase,N * f_uta: *ACI 17.4.1.2*

Effective Cross-Sectional Area of Anchor in Tension, A_se,N:				
Anchor Size =	override	1	inches	
Area, A_se,N =		0.61	inches^2	
Tensile Strength of Anchor, futa <= 1.9*fy <= 125 ksi				
fy =		55	ksi	
fu =		75	ksi	
1.9*fy =	override	104.5	ksi	
Controlling Tensile Strenght, f_uta =		75	ksi	
Nsa =		45.5	kips	
phi_ts*Nsa =		34.1	kips	

Determine Nominal Concrete Breakout Strength of a Single Anchor in Tension, Ncb = A_nc * Nb / (9*hef^2) * psi_ed,N * psi_c,N * psi_cp,N: *ACI 17.4.2.1a*

Psi Factors:				
psi_ed,N [Modification factor for tensile strength based on proximity to edges]				*ACI 17.4.2.5*
Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =		16	inches	OK, <= 20*Dia.
Minimum edge distance, Ca_min =		6.125	inches	
psi_ed,N =		0.777		
psi_c,N [Modification factor for tensile strength based on presence or absence of cracks]				*ACI 17.4.2.6*
psi_c, N = (1.0 when cracking at service loads, 1.4 when no cracking at service loads) =		1.0		
psi_cp,N [Modification factor for post-installed anchors intended for use in uncracked concrete]				*ACI 17.4.2.7*
psi_cp,N =	Supplementary Reinforcement Included, Therefore =	1.0	for CIP anchors	
Concrete Breakout Strength of a Single Anchor in Tension in Cracked Concrete, Nb =		97.15	kips	*ACI 17.4.2.2*
Ncb =		10.90	kips	
phi_tc*Ncb =		8.18	kips	

Determine Nominal Concrete Breakout Strength of an Anchor Group in Tension, Ncbg = A_nc * Nb / (9*hef^2) *psi_ec,N* psi_ed,N * psi_c,N * psi_cp,N: *ACI 17.4.2.1b*

Psi Factors:				
psi_ec,N [Modification factor for anchor groups loaded eccentrically in tension]				*ACI 17.4.2.4*
Eccentricity, e'N =		0	inches	
psi_ec,N =		1.00		
psi_ed,N [Modification factor for tensile strength based on proximity to edges]				*ACI 17.4.2.5*
Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =		16	inches	OK, <= 20*Dia.
Minimum edge distance, Ca_min =		6.125	inches	
psi_ed,N =		0.777		
psi_c,N [Modification factor for tensile strength based on presence or absence of cracks]				*ACI 17.4.2.6*
psi_c, N = (1.0 when cracking at service loads, 1.4 when no cracking at service loads) =		1.0		
psi_cp,N [Modification factor for post-installed anchors intended for use in uncracked concrete]				*ACI 17.4.2.7*
psi_cp,N =	Supplementary Reinforcement Included, Therefore =	1.0	for CIP anchors	
Basic Concrete Breakout Strength of a Single Anchor in Tension in Cracked Concrete, Nb =	for normal weight concrete	97.1	kips	*ACI 17.4.2.2*
Ncbg =		21.22	kips	
phi_tc*Ncbg =		15.91	kips	

Determine Nominal Pullout Strength of a Single Anchor or Anchor Group in Tension, Npn = Np *psi_c,p: *ACI 17.4.3.1*

Psi Factors:				
psi_c,p [Modification factor for pull-out strength based on cracking]		1		*ACI 17.4.3.6*
Pullout Strength for a Single Anchor, Np = 8*Abrg*f'c =	conservative, not accounting for hooked ends	37.22	kips	
phi_tc_pullout*Nag for Single Anchor =		27.91	kips	
phi_tc_pullout*Nag for Anchor Group =		55.82	kips	

Determine Concrete Side Face Blowout of a Headed Single Anchor in Tension, Nsb = 160*Ca1*Abrg^0.5*lambda_a*f'c^0.5: *ACI 17.4.4.1*

Check Applicability: Applicable if hef > 2.5*Ca1:				
hef =		16	inches	
2.5*Ca1 =		15.3125	inches	
Status of Applicability =		Not Applicable		
Side Face Blowout Strength for a Single Anchor, Nsb = 160*Ca1*Abrg^0.5*lambda_a*f'c^0.5 =		66.8	kips	
phi_tc_pullout*Nsb for Single Anchor =		50.13	kips	

Determine Concrete Side Face Blowout of Multiple Headed Anchors in Tension, Nsbg = (1+s/6/Ca1)*Nsb:				*ACI 17.4.4.2*
Check Applicability: Applicable if hef > 2.5*Ca1 and anchor spacing < 6*Ca1:				
hef =		16	inches	
2.5*Ca1 =		15.3125	inches	
Spacing =		5.75	inches	
6*Ca1 =		36.75	inches	
Status of Applicability =		Not Applicable		
Side Face Blowout Strength for Multiple Achors, Nsbg = (1+2/6/Ca1)*Nsb =		77.3	kips	
phi_tc_pullout*Nsbg for Multiple Anchors =		57.97	kips	
Summary of Design Strengths for Tension:				
Steel Strength, phi*Nsa =		68.2	kips	
Concrete Breakout Strength, phi*Ncb =	Controls	15.9	kips	
Pullout Strength, phi*Npn =		55.8	kips	
Sideface Blowout Strength, phi*Nsb =		N/A	kips	
Controlling Tension Capacity =		15.9	kips	
Check Tensile Capacity vs. Tensile Load				
Factored Tension Force, Nu =		13.2	kips	
Controlling Tension Capacity =		15.9	kips	

Selected Anchor has Sufficient Tensile Capacity

CIP ANCHOR SHEAR RESISTANCE:

Nominal Shear Resistance, Vr = phi_vs*0.6*Vsa <= phi_vc*Vcb <= phi_vp*Vcp				
Phi Factors:				
Steel Classification =		Ductile		*ACI 2.3*
Supplementary Reinforcement Included =		Yes		*ACI 17.3.3*
phi_vs =		0.65		
phi_vc =		0.75		
phi_vp =		0.75		
Determine Nominal Steel Strength of Anchor in Shear, Vsa = Ase,V * f_uta:				*ACI 17.5.1.2*
Effective Cross-Sectional Area of Anchor in Tension, A_se,N:				
Anchor Diameter =	override	1	inches	
Area, A_se,V =		0.606	inches^2	
Tensile Strength of Anchor, futa <= 1.9*fy <= 125 ksi				
fy =		55	ksi	
fu =		75	ksi	
1.9*fy =	override	104.5	ksi	
Controlling Tensile Strenght, f_uta =		75	ksi	
Vsa =		27.3	kips	
phi_vs*Vsa =		17.7	kips	
Determine Nominal Concrete Breakout Strength in Shear for a Single Anchor, Vcb = A_vc * Vb / (4.5*Ca1^2) * psi_ed,V * psi_c,V * psi_h,V * psi_p,V:				*ACI 17.5.2.1a*
Psi Factors:				
psi_ed,V [Modification factor for shear strength based on proximity to edges]				*ACI 17.5.2.6*
Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =		16	inches	OK, <= 20*Dia.
Minimum edge distance, Ca_min =	override	6.125	inches	
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =		13	inches	
Ca2 = Distance from C/L anchor to edge of concrete in direction perpendicular to Ca1 =	6.125	6.125	inches	
Direction of Shear (perpendicular is conservative) =		Perpendicular		
psi_ed,V =		0.8		
psi_c,V [Modification factor for shear strength based on presence or absence of cracks and supplemental reinforcement]				*ACI 17.5.2.7*
Where analysis shows no cracking at service loads, psi_c, V =		1.4		
Where analysis shows cracking at service loads and no supplemental rebar or edge rebar <#4, psi_c, V =		1.0		
Where analysis shows cracking at service loads and a #4 bar or greater between anchor and edge, psi_c, V =		1.2		
Where analysis shows cracking at service loads & >= #4 bar between edge & >=#4 stirrups spaced <=4", psi_c, V =		1.4		
	override			
psi_c,V =		1.2		
psi_h,V [Modification factor for shear strength of anchors located in members with ha < 1.5*Ca1]				*ACI 17.5.2.8*
Concrete member thickness, ha =		19	inches	
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =		13	inches	
psi_h,V = max(sqrt(1.5*Ca1/ha),1.0) =		1.0		
psi_p,V [Modification factor for shear strength based on loading direction]				*ACI 17.5*
psi_p,V =		1.00		
Projected Area of Concrete Failure Surface, Avc:				
H = min(member depth, 1.5*Ca1) =		19	inches	
S1 = min(Spacing/2,perpendicular edge distance(Ca2),1.5*edge distance(Ca1)) =		6.125	inches	
S2 = min(Spacing/2,perpendicular edge distance,1.5*edge distance) =		2.875	inches	
Avc = H(S1+S2) =		171.0	inches^2	

Concrete Breakout Strength of a Single Anchor in Shear in Cracked Concrete, Vb:				*ACI 17.5.2.2*
le = hef < 8*dia. =		8	inches	
diameter =		1	inches	
f'c =		4000	psi	
Ca1 =		13	inches	
Vb = min[7*(le/dia)^0.2 * dia^0.5 * f'c^0.5 * Ca1^1.5 , 9 *f'c^0.5 * ca1^1.5]=		26.680	kips	
Vcb =		5.79	kips	
phi_vc*Vcb =		4.34	kips	
Determine Nominal Concrete Breakout Strength in Shear for an Anchor Group, Vcbg = A_vc * Vb / (4.5*Ca1^2) * psi_ec,V * psi_ed,V * psi_c,V * psi_h,V * psi_p,V:				*ACI 17.5.2.1b*
Psi Factors:				
psi_ec,V [Modification factor for anchor group loaded eccentrically in shear]				*ACI 17.5.2.5*
Eccentricity, e'V =		0	inches	
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =		13	inches	
psi_ec,V =		1.00		
psi_ed,V [Modification factor for shear strength based on proximity to edges]				*ACI 17.5.2.6*
Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =		16	inches	Warning, Exceeds 20*Dia.
Minimum edge distance, Ca_min =	override	6.125	inches	
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =		13	inches	
Ca2 = Distance from C/L anchor to edge of concrete in direction perpendicular to Ca1 =		5.75	inches	
Direction of Shear (perpendicular is conservative) =		Perpendicular		
psi_ed,V =		0.79		
psi_c,V [Modification factor for shear strength based on presence or absence of cracks and supplemental reinforcement]				*ACI 17.5.2.7*
Where analysis shows no cracking at service loads, psi_c, V =		1.4		
Where analysis shows cracking at service loads and no supplemental rebar or edge rebar <#4, psi_c, V =		1.0		
Where analysis shows cracking at service loads and a #4 bar or greater between anchor and edge, psi_c, V =		1.2		
Where analysis shows cracking at service loads & >= #4 bar between edge & >=#4 stirrups spaced <=4", psi_c, V =		1.4		
	override			
psi_c,V =		1.2		
psi_h,V [Modification factor for shear strength of anchors located in members with ha < 1.5*Ca1]				*ACI 17.5.2.8*
Concrete member thickness, ha =		19	inches	
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =		13	inches	
psi_h,V = max(sqrt(1.5*Ca1/ha),1.0) =		1.0		
psi_p,V [Modification factor for shear strength based on loading direction]				*ACI 17.5*
psi_p,V =		1.00		
Projected Area of Concrete Failure Surface, Avc:				
Avc = H(S1+S2) =		342.0	inches^2	
Concrete Breakout Strength of a Single Anchor in Shear in Cracked Concrete, Vb:				*ACI 17.5.2.2*
le = hef < 8*dia. =		8	inches	
diameter =		1	inches	
f'c =		4000	psi	
Ca1 =		13	inches	
Vb = min[7*(le/dia)^0.2 * dia^0.5 * f'c^0.5 * Ca1^1.5 , 9 *f'c^0.5 * ca1^1.5]=		26.68	kips	
Vcb =		11.50	kips	
phi_vc*Vcb =		8.63	kips	
Determine Nominal Concrete Pryout Strength for a Single Anchor, Vcp = Kcp*Ncp:				*ACI 17.5.3.1(a)*
Kcp = 1.0 for hef < 2.5" and 2.0 for hef >= 2.5" =		2		
Nominal Concrete Pryout Strength, Ncp = Ncb for cast in place anchors =		10.90	kips	
Vcp =		21.81	kips	
phi_vp*Vcp =		16.36	kips	
Determine Nominal Concrete Pryout Strength for a Group of Anchors, Vcpg = Kcp*Ncpg:				*ACI 17.5.3.1(b)*
Kcp = 1.0 for hef < 2.5" and 2.0 for hef >= 2.5" =		2		
Nominal Concrete Pryout Strength, Ncpg = Ncbg for cast in place anchors =		21.22	kips	
Vcp =		42.43	kips	
phi_vp*Vcp =		31.83	kips	
Summary of Design Strengths for Shear:				
Steel Strength, phi*Vsa =		106.4	kips	
Concrete Breakout Strength, phi*Vcb =		8.6	kips	
Pryout Strength, phi*Vcp =		31.8	kips	
Controlling Shear Capacity =		8.6	kips	

Check Shear Capacity vs. Shear Load

Factored Shear Force, Vu =	0.59	kips
Controlling Shear Capacity =	8.63	kips

Selected Anchor has Sufficient Shear Capacity

SHEAR & TENSION INTERACTION ANALYSIS **ACI 17.6**

Vu/(phi*Vn) =	0.07
Nu/(phi*Nn) =	0.83

For Vu/(phi*Vn) <=0.2: Nu <= phi*Nn
Interaction Capacity is Sufficient

For Nu/(phi*Nn) <=0.2: Vu <= phi * Vn
Not Applicable

For Vu/(phi*Vn) > 0.2 and Nu/(phi*Nn) > 0.2: Nu/(phi*Nn) + Vu/(phi*Vn) <=1.2
Not Applicable
Interaction Value = N/A

Project: USH 2 over St. Louis River			
Structure Number: B-16-38		**Project #:** 22114	
Task: Light Pole CIP Anchor Analysis - loading perpendicular to face of Parapet			
Design By: WAH	**Date:** 12/18/2024	**Checked By:** SKH	**Date:** 12/19/2024

KL Engineering

CONCRETE MASONRY CIP ANCHOR DESIGN PROGRAM

DESIGN LOADS:	Enter loads on single anchor or on group		
Factored Tension Force, Nu =	*moment is less perpendicular to parapet* 8.27'-k *12"/' /5.75"	17.25	kips
Factored Shear Force, Vu =		0.52	kips
ANCHOR PROPERTIES:			
Proposed Anchor Size =		1	inches
Analyze as Single Anchor or Group =	Group Analysis Required	Group	
If Group, # of Anchors Effective in Tension =	For force in rebar or bolt only (not concrete)	3	anchors
If Group, # of Anchors Effective in Shear =	For force in rebar or bolt only (not concrete)	6	anchors
Yield Strength of Anchor, fy =		55	ksi
Tensile Strength of Anchor, fut =		75	ksi
Condition of Concrete =			
Dry or Wet (Saturated) =		Saturated	
Cracked or Uncracked at Service Loads =		Cracked	
Compressive Strength =		4000	psi
Proposed Embedmen Depth =	OK, Below Limit of 20*Dia.	16	inches
Depth of Member =		19	inches
Single Anchor Edge Distance & Spacing:			
Torqued or Not Torgued =		Not Torqued	
Minimum Edge Distance =		2	inches
Minimum Spacing =		4	inches
Left Side:			
Edge or Anchor =		Edge	
Distance to Edge or Anchor Spacing =	OK, Meets Minimum Edge Distance Requirement	13	inches
Right Side:			
Edge or Anchor =		Anchor	
Distance to Edge or Anchor Spacing =	OK, Meets Minimum Spacing Requirement	5	inches
Front:			
Edge or Anchor =		Edge	
Distance to Edge or Anchor Spacing =	OK, Meets Minimum Edge Distance Requirement	11.875	inches
Back:			
Edge or Anchor =		Edge	
Distance to Edge or Anchor Spacing =	OK, Meets Minimum Edge Distance Requirement	6.125	inches
ANCHOR GEOMETRIC PROPERTIES:			
Determine Projected Concrete Breakout Area of a Single Anchor, A_Nc:			
A_Nco = 9 * hef^2 =		2304.0	inches^2
S = min(1.5*hef, spacing/2, edge distance {ca})			
Left: S =		13	inches
Right: S =		2.5	inches
Front: S =		11.875	inches
Back: S =		6.125	inches
A_Nc =		279.0	inches^2

Calculate A_Nc per ACI Figure 17.4.2.1 for Anchor Group

1.5*hef =		24	inches
Width of Group =		36	inches
Depth of Group =	ave. width accounting for sloped sides	20	inches
A_Nc =		720	inches^2

Calculate A_vc per ACI Figure 17.5.2.1b for Anchor Group override

Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =		6.13	inches
1.5*Ca1 =		9.19	inches
Member Depth, ha =		19.00	inches
Width of Group =	10+9.19*2	28.38	inches
Depth of Group =		9.19	inches
A_vc =		260.7	inches^2

CIP ANCHOR TENSILE RESISTANCE:

Nominal Tensile Resistance, Nr = phi_ts*Nsa <= phi_tc*Ncb <= phi_tc*Na

Phi Factors:

Steel Classification =		Ductile		*ACI 2.3*
Supplementary Reinforcement Included =		Yes		*ACI 17.3.3*
phi_ts =		0.75		
phi_tc =		0.75		
phi_tc_pullout =		0.75		

Determine Nominal Steel Strength of Anchor in Tension, Nsa = Ase,N * f_uta: *ACI 17.4.1.2*

Effective Cross-Sectional Area of Anchor in Tension, A_se,N:				
Anchor Size =	override	1	inches	
Area, A_se,N =		0.61	inches^2	
Tensile Strength of Anchor, futa <= 1.9*fy <= 125 ksi				
fy =		55	ksi	
fu =		75	ksi	
1.9*fy =	override	104.5	ksi	
Controlling Tensile Strenght, f_uta =		75	ksi	
Nsa =		45.5	kips	
phi_ts*Nsa =		34.1	kips	

Determine Nominal Concrete Breakout Strength of a Single Anchor in Tension, Ncb = A_nc * Nb / (9*hef^2) * psi_ed,N * psi_c,N * psi_cp,N: *ACI 17.4.2.1a*

Psi Factors:				
psi_ed,N [Modification factor for tensile strength based on proximity to edges]				*ACI 17.4.2.5*
Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =		16	inches	OK, <= 20*Dia.
Minimum edge distance, Ca_min =		6.125	inches	
psi_ed,N =		0.777		
psi_c,N [Modification factor for tensile strength based on presence or absence of cracks]				*ACI 17.4.2.6*
psi_c, N = (1.0 when cracking at service loads, 1.4 when no cracking at service loads) =		1.0		
psi_cp,N [Modification factor for post-installed anchors intended for use in uncracked concrete]				*ACI 17.4.2.7*
psi_cp,N =	Supplementary Reinforcement Included, Therefore =	1.0	for CIP anchors	
Concrete Breakout Strength of a Single Anchor in Tension in Cracked Concrete, Nb =		97.15	kips	*ACI 17.4.2.2*
Ncb =		9.14	kips	
phi_tc*Ncb =		6.85	kips	

Determine Nominal Concrete Breakout Strength of an Anchor Group in Tension, Ncbg = A_nc * Nb / (9*hef^2) *psi_ec,N* psi_ed,N * psi_c,N * psi_cp,N: *ACI 17.4.2.1b*

Psi Factors:				
psi_ec,N [Modification factor for anchor groups loaded eccentrically in tension]				*ACI 17.4.2.4*
Eccentricity, e'N =		0	inches	
psi_ec,N =		1.00		
psi_ed,N [Modification factor for tensile strength based on proximity to edges]				*ACI 17.4.2.5*
Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =		16.000	inches	OK, <= 20*Dia.
Minimum edge distance, Ca_min =		6.125	inches	
psi_ed,N =		0.777		
psi_c,N [Modification factor for tensile strength based on presence or absence of cracks]				*ACI 17.4.2.6*
psi_c, N = (1.0 when cracking at service loads, 1.4 when no cracking at service loads) =		1.0		
psi_cp,N [Modification factor for post-installed anchors intended for use in uncracked concrete]				*ACI 17.4.2.7*
psi_cp,N =	Supplementary Reinforcement Included, Therefore =	1.0	for CIP anchors	
Basic Concrete Breakout Strength of a Single Anchor in Tension in Cracked Concrete, Nb =	for normal weight concrete	97.1	kips	*ACI 17.4.2.2*
Ncbg =		23.57	kips	
phi_tc*Ncbg =		17.68	kips	

Determine Nominal Pullout Strength of a Single Anchor or Anchor Group in Tension, Npn = Np *psi_c,p: *ACI 17.4.3.1*

Psi Factors:				
psi_c,p [Modification factor for pull-out strength based on cracking]		1		*ACI 17.4.3.6*
Pullout Strength for a Single Anchor, Np = 8*Abrg*f'c =	conservative, not accounting for hooked ends	37.22	kips	
phi_tc_pullout*Nag for Single Anchor =		27.91	kips	
phi_tc_pullout*Nag for Anchor Group =		83.74	kips	

Determine Concrete Side Face Blowout of a Headed Single Anchor in Tension, Nsb = 160*Ca1*Abrg^0.5*lambda_a*f'c^0.5: *ACI 17.4.4.1*

Check Applicability: Applicable if hef > 2.5*Ca1:				
hef =		16	inches	
2.5*Ca1 =		15.3	inches	
Status of Applicability =		Not Applicable		
Side Face Blowout Strength for a Single Anchor, Nsb = 160*Ca1*Abrg^0.5*lambda_a*f'c^0.5 =		66.8	kips	
phi_tc_pullout*Nsb for Single Anchor =		50.13	kips	

Determine Concrete Side Face Blowout of Multiple Headed Anchors in Tension, Nsbg = (1+s/6/Ca1)*Nsb: *ACI 17.4.4.2*

Check Applicability: Applicable if hef > 2.5*Ca1 and anchor spacing < 6*Ca1:

hef =	16	inches
2.5*Ca1 =	15.3	inches
Spacing =	5	inches
6*Ca1 =	36.75	inches
Status of Applicability =	Not Applicable	

Side Face Blowout Strength for Multiple Achors, Nsbg = (1+2/6/Ca1)*Nsb =	75.9	kips
phi_tc_pullout*Nsbg for Multiple Anchors =	56.95	kips

Summary of Design Strengths for Tension:

Steel Strength, phi*Nsa =		102.3	kips
Concrete Breakout Strength, phi*Ncb =	Controls	17.7	kips
Pullout Strength, phi*Npn =		83.7	kips
Sideface Blowout Strength, phi*Nsb =		N/A	kips

Controlling Tension Capacity = 17.7 kips

Check Tensile Capacity vs. Tensile Load

Factored Tension Force, Nu =	17.3	kips
Controlling Tension Capacity =	17.7	kips

Selected Anchor has Sufficient Tensile Capacity

CIP ANCHOR SHEAR RESISTANCE:

Nominal Shear Resistance, Vr = phi_vs*0.6*Vsa <= phi_vc*Vcb <= phi_vp*Vcp

Phi Factors:

Steel Classification =	Ductile	*ACI 2.3*
Supplementary Reinforcement Included =	Yes	*ACI 17.3.3*
phi_vs =	0.65	
phi_vc =	0.75	
phi_vp =	0.75	

Determine Nominal Steel Strength of Anchor in Shear, Vsa = Ase,V * f_uta: *ACI 17.5.1.2*

Effective Cross-Sectional Area of Anchor in Tension, A_se,N:

Anchor Diameter =	override	1	inches
Area, A_se,V =		0.606	inches^2

Tensile Strength of Anchor, futa <= 1.9*fy <= 125 ksi

fy =		55	ksi
fu =		75	ksi
1.9*fy =	override	104.5	ksi
Controlling Tensile Strenght, f_uta =		75	ksi

Vsa =	27.3	kips
phi_vs*Vsa =	17.7	kips

Determine Nominal Concrete Breakout Strength in Shear for a Single Anchor, Vcb = A_vc * Vb / (4.5*Ca1^2) * psi_ed,V * psi_c,V * psi_h,V * psi_p,V: *ACI 17.5.2.1a*

Psi Factors:

psi_ed,V [Modification factor for shear strength based on proximity to edges] *ACI 17.5.2.6*

Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =		16	inches	OK, <= 20*Dia.
Minimum edge distance, Ca_min =	override	6.125	inches	
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =		6.125	inches	
Ca2 = Distance from C/L anchor to edge of concrete in direction perpendicular to Ca1 =	6.125	6.125	inches	
Direction of Shear (perpendicular is conservative) =		Perpendicular		

psi_ed,V = 0.9

psi_c,V [Modification factor for shear strength based on presence or absence of cracks and supplemental reinforcement] *ACI 17.5.2.7*

Where analysis shows no cracking at service loads, psi_c, V =	1.4
Where analysis shows cracking at service loads and no supplemental rebar or edge rebar <#4, psi_c, V =	1.0
Where analysis shows cracking at service loads and a #4 bar or greater between anchor and edge, psi_c, V =	1.2
Where analysis shows cracking at service loads & >= #4 bar between edge & >=#4 stirrups spaced <=4", psi_c, V =	1.4

override

psi_c,V = 1.2

psi_h,V [Modification factor for shear strength of anchors located in members with ha < 1.5*Ca1] *ACI 17.5.2.8*

Concrete member thickness, ha =	19	inches
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =	6.125	inches

psi_h,V = max(sqrt(1.5*Ca1/ha),1.0) = 1.0

psi_p,V [Modification factor for shear strength based on loading direction] *ACI 17.5*

psi_p,V = 1.00

Projected Area of Concrete Failure Surface, Avc:

H = min(member depth, 1.5*Ca1) =	9.1875	inches
S1 = min(Spacing/2,perpendicular edge distance(Ca2),1.5*edge distance(Ca1)) =	9.1875	inches
S2 = min(Spacing/2,perpendicular edge distance,1.5*edge distance) =	2.5	inches

Avc = H(S1+S2) = 107.4 inches^2

Concrete Breakout Strength of a Single Anchor in Shear in Cracked Concrete, Vb:			*ACI 17.5.2.2*
le = hef < 8*dia. =	8	inches	
diameter =	1	inches	
f'c =	4000	psi	
Ca1 =	6.125	inches	
Vb = min[7*(le/dia)^0.2 * dia^0.5 * f'c^0.5 * Ca1^1.5 , 9 *f'c^0.5 * ca1^1.5]=	8.628	kips	
Vcb =	5.93	kips	
phi_vc*Vcb =	4.45	kips	
Determine Nominal Concrete Breakout Strength in Shear for an Anchor Group, Vcbg = A_vc * Vb / (4.5*Ca1^2) * psi_ec,V * psi_ed,V * psi_c,V * psi_h,V * psi_p,V:			*ACI 17.5.2.1b*
Psi Factors:			
psi_ec,V [Modification factor for anchor group loaded eccentrically in shear]			*ACI 17.5.2.5*
Eccentricity, e'V =	0	inches	
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =	6.125	inches	
psi_ec,V =	1.00		
psi_ed,V [Modification factor for shear strength based on proximity to edges]			*ACI 17.5.2.6*
Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =	16	inches	Warning, Exceeds 20*Dia.
Minimum edge distance, Ca_min = override	6.125	inches	
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =	6.125	inches	
Ca2 = Distance from C/L anchor to edge of concrete in direction perpendicular to Ca1 =	5	inches	
Direction of Shear (perpendicular is conservative) =	Perpendicular		
psi_ed,V =	0.86		
psi_c,V [Modification factor for shear strength based on presence or absence of cracks and supplemental reinforcement]			*ACI 17.5.2.7*
Where analysis shows no cracking at service loads, psi_c, V =	1.4		
Where analysis shows cracking at service loads and no supplemental rebar or edge rebar <#4, psi_c, V =	1.0		
Where analysis shows cracking at service loads and a #4 bar or greater between anchor and edge, psi_c, V =	1.2		
Where analysis shows cracking at service loads & >= #4 bar between edge & >=#4 stirrups spaced <=4", psi_c, V =	1.4		
override			
psi_c,V =	1.2		
psi_h,V [Modification factor for shear strength of anchors located in members with ha < 1.5*Ca1]			*ACI 17.5.2.8*
Concrete member thickness, ha =	19	inches	
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =	6.125	inches	
psi_h,V = max(sqrt(1.5*Ca1/ha),1.0) =	1.0		
psi_p,V [Modification factor for shear strength based on loading direction]			*ACI 17.5*
psi_p,V =	1.00		
Projected Area of Concrete Failure Surface, Avc:			
Avc = H(S1+S2) =	260.7	inches^2	
Concrete Breakout Strength of a Single Anchor in Shear in Cracked Concrete, Vb:			*ACI 17.5.2.2*
le = hef < 8*dia. =	8	inches	
diameter =	1	inches	
f'c =	4000	psi	
Ca1 =	6.125	inches	
Vb = min[7*(le/dia)^0.2 * dia^0.5 * f'c^0.5 * Ca1^1.5 , 9 *f'c^0.5 * ca1^1.5]=	8.63	kips	
Vcb =	13.81	kips	
phi_vc*Vcb =	10.35	kips	
Determine Nominal Concrete Pryout Strength for a Single Anchor, Vcp = Kcp*Ncp:			*ACI 17.5.3.1(a)*
Kcp = 1.0 for hef < 2.5" and 2.0 for hef >= 2.5" =	2		
Nominal Concrete Pryout Strength, Ncp = Ncb for cast in place anchors =	9.14	kips	
Vcp =	18.27	kips	
phi_vp*Vcp =	13.70	kips	
Determine Nominal Concrete Pryout Strength for a Group of Anchors, Vcpg = Kcp*Ncpg:			*ACI 17.5.3.1(b)*
Kcp = 1.0 for hef < 2.5" and 2.0 for hef >= 2.5" =	2		
Nominal Concrete Pryout Strength, Ncpg = Ncbg for cast in place anchors =	23.57	kips	
Vcp =	47.15	kips	
phi_vp*Vcp =	35.36	kips	
Summary of Design Strengths for Shear:			
Steel Strength, phi*Vsa =	106.4	kips	
Concrete Breakout Strength, phi*Vcb =	10.4	kips	
Pryout Strength, phi*Vcp =	35.4	kips	
Controlling Shear Capacity =	10.4	kips	

Check Shear Capacity vs. Shear Load

Factored Shear Force, Vu =	0.52	kips
Controlling Shear Capacity =	10.35	kips

Selected Anchor has Sufficient Shear Capacity

SHEAR & TENSION INTERACTION ANALYSIS **ACI 17.6**

Vu/(phi*Vn) =	0.05
Nu/(phi*Nn) =	0.98

For Vu/(phi*Vn) <=0.2: Nu <= phi*Nn
Interaction Capacity is Sufficient

For Nu/(phi*Nn) <=0.2: Vu <= phi * Vn
Not Applicable

For Vu/(phi*Vn) > 0.2 and Nu/(phi*Nn) > 0.2: Nu/(phi*Nn) + Vu/(phi*Vn) <=1.2
Not Applicable
Interaction Value = N/A

Project: *USH 2 over St. Louis River*				
Structure Number: *B-16-38*		**Project #:** *22114*		
Task: *Parapet Adhesive Anchor Analysis - Median Parapets*				
Design By: *WAH*	**Date:** *12/17/2024*	**Checked By:** *SKH*	**Date:** *12/18/2024*	

KL Engineering

CONCRETE MASONRY ADHESIVE ANCHOR DESIGN PROGRAM

DESIGN LOADS: Enter loads on single a

Factored Tension Force, Nu =		0
Continuous Factored Tension Force, Nus {from loads that are always present} =		0
Factored Shear Force, Vu =		0

ANCHOR PROPERTIES:

Proposed Bar Size =			#
Analyze as Single Anchor or Group =		Group Analysis Required	Group
If Group, # of Anchors Effective in Tension =	10' width, all new anchors - accounts for one side	For force in rebar or bolt only (not concrete)	16
If Group, # of Anchors Effective in Shear =	10' width, all new anchors - accounts for two sides	For force in rebar or bolt only (not concrete)	32
Condition of Concrete =			
Dry or Wet (Saturated) =			Saturated
Cracked or Uncracked at Service Loads =			Cracked
Compressive Strength =			4000
Proposed Embedmen Depth =		OK, Below Limit of 20*Dia.	5.25
Depth of Member =			9.00

<u>Single Anchor Edge Distance & Spacing:</u> Note: See ACI 17.4.2.3 when located near 3 or more edges

Minimum Edge Distance = 6*dia. =		3.75
Minimum Spacing = 6*dia. =		3.75
Left Side:		
Edge or Anchor =		Anchor
Distance to Edge or Anchor Spacing =	OK, Meets Minimum Spacing Requirement	8.00
Right Side:		
Edge or Anchor =		Anchor
Distance to Edge or Anchor Spacing =	OK, Meets Minimum Spacing Requirement	8.00
Front:		
Edge or Anchor =		Edge
Distance to Edge or Anchor Spacing =	OK, Meets Minimum Edge Distance Requirement	4.00
Back:		
Edge or Anchor =		Edge
Distance to Edge or Anchor Spacing =	OK, Meets Minimum Edge Distance Requirement	90.00

ANCHOR GEOMETRIC PROPERTIES:

Determine Projected Concrete Breakout Area of a Single Adhesive Anchor, A_Nc:

S = min(1.5*hef, spacing/2, edge distance {ca})

Left: S =	4
Right: S =	4
Front: S =	4
Back: S =	7.875
A_Nc =	95.0

Calculate A_Nc per ACI Figure 17.4.2.1 for Anchor Group

1.5*hef =	7.875	inches	
Width of Group =	135.75	inches	
Depth of Group =	11.88	inches	
A_Nc =			1612.0

Determine Projected Influence Area of a Single Adhesive Anchor, A_Na:

S = min(C_Na, spacing/2, edge distance {ca})

tau_uncr =	510
C_Na = 10 * Dia. * (tau_uncr/1100)^0.5 =	4.26
Left: S =	4.00
Right: S =	4.00
Front: S =	4.00
Back: S =	4.26
A_Na =	66.0

Calculate A_Na per ACI Figure 17.4.5.1 for Anchor Group

C_Na = 10 * Dia. * (tau_uncr/1100)^0.5 = 4.26 inches
Width of Group = 128.51 inches
Depth of Group = 8.26 inches

A_Na = 1060.9

Calculate A_vc per ACI Figure 17.5.2.1b for Anchor Group override

Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear = 4.00 inches ACI Case 1, 1/2 load tc
1.5*Ca1 = 6.00 inches
Member Depth, ha = 9.00 inches
Width of Group = 132.00 inches
Depth of Group = 4.00 inches

A_vc = 528.0

ADHESIVE ANCHOR TENSILE RESISTANCE:

Nominal Tensile Resistance, Nr = phi_ts*Nsa <= phi_tc*Ncb <= phi_tc*Na

Phi Factors:

Steel Classification = Ductile
Supplementary Reinforcement Included = Yes
phi_ts = 0.75
phi_tc = 0.65
phi_tc_pullout = 0.65

Determine Nominal Steel Strength of Anchor in Tension, Nsa = Ase,N * f_uta:

Effective Cross-Sectional Area of Anchor in Tension, A_se,N:
Bar # = override # 5
Area, A_se,N = 0.31 inches^2
Tensile Strength of Anchor, futa <= 1.9*fy <= 125 ksi
fy = 60 ksi
fu = 90 ksi
1.9*fy = override 114 ksi
Controlling Tensile Strenght, f_uta = 90 ksi

Nsa = 27.6 kips
phi_ts*Nsa = 20.7 kips

Determine Nominal Concrete Breakout Strength of a Single Anchor in Tension, Ncb = A_nc * Nb / (9*hef^2) * psi_ed,N * psi_c,N * psi_cp,N:

Psi Factors:
psi_ed,N [Modification factor for tensile strength based on proximity to edges]
Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter = 5.25 inches
Minimum edge distance, Ca_min = 4 inches
psi_ed,N = 0.852

psi_c,N [Modification factor for tensile strength based on presence or absence of cracks]
psi_c, N = (1.0 when cracking at service loads, 1.4 when no cracking at service loads) = 1.0

psi_cp,N [Modification factor for post-installed anchors intended for use in uncracked concrete]
Critical Edge Distance, Cac = 2*hef = 10.5 inches
psi_cp,N = Supplementary Reinforcement Included, Therefore = 1.000

Concrete Breakout Strength of a Single Anchor in Tension in Cracked Concrete, Nb = 12.93 kips

Ncb = 4.22 kips
phi_tc*Ncb = 2.74 kips

Determine Nominal Concrete Breakout Strength of an Anchor Group in Tension, Ncbg = A_nc * Nb / (9*hef^2) *psi_ec,N* psi_ed,N * psi_c,N * psi_cp,N:

Psi Factors:
psi_ec,N [Modification factor for anchor groups loaded eccentrically in tension]
Eccentricity, e'N = 0.00 inches
psi_ec,N = 1.00

psi_ed,N [Modification factor for tensile strength based on proximity to edges]
Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter = 5.25 inches
Minimum edge distance, Ca_min = 4 inches
psi_ed,N = 0.852

psi_c,N [Modification factor for tensile strength based on presence or absence of cracks]
psi_c, N = (1.0 when cracking at service loads, 1.4 when no cracking at service loads) = 1.0

psi_cp,N [Modification factor for post-installed anchors intended for use in uncracked concrete]
Critical Edge Distance, Cac = 2*hef = 10.5 inches
psi_cp,N = Supplementary Reinforcement Included, Therefore = 1.000

Basic Concrete Breakout Strength of a Single Anchor in Tension in Cracked Concrete, Nb = for normal weight concrete 10.3 kips

Ncbg = 57.31 kips
phi_tc*Ncbg = 37.25 kips

Determine Nominal Bond Strength of a Single Anchor in Tension, Na = A_na * Nba / (4*C_na^2) * psi_ed,Na * psi_cp,Na:

Psi Factors:

psi_ed,Na [Modification factor for tensile strength of adhesive anchors based on proximity to edges]

Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =	5.25	inches
Minimum edge distance, Ca_min =	4	inches
C_Na = distance required to develop full bond strength =	4.26	inches
psi_ed,Na =	0.982	

psi_cp,Na [Modification factor for pull-out strength of adhesive anchors]

Critical Edge Distance, Cac = 2*hef =		10.5	inches
psi_cp,Na =	Supplementary Reinforcement Included, Therefore =	1.00	

Bond Strength in Tension of a Single Adhesive Anchor, Nba = tau_cr * pi * dia. * hef:

tau =	410	psi
Nba =	4.2	kips
Na =	3.78	kips
phi_tc_pullout*Na =	2.46	kips

Determine Nominal Bond Strength of an Anchor Group in Tension, Nag = A_na * Nba / (4*C_na^2) *psi_ec,Na* psi_ed,Na * psi_cp,Na:

Psi Factors:

psi_ec,N [Modification factor for anchor groups loaded eccentrically in tension]

Eccentricity, e'N =	0	inches
psi_ec,N =	1.00	

psi_ed,Na [Modification factor for tensile strength of adhesive anchors based on proximity to edges]

Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =	5.25	inches
Minimum edge distance, Ca_min =	4	inches
C_Na = distance required to develop full bond strength =	4.26	inches
psi_ed,Na =	0.982	

psi_cp,Na [Modification factor for pull-out strength of adhesive anchors]

Critical Edge Distance, Cac = 2*hef =		10.5	inches
psi_cp,Na =	Supplementary Reinforcement Included, Therefore =	1.00	

Bond Strength in Tension of a Single Adhesive Anchor, Nba = tau_cr * pi * dia. * hef:

tau =	410	psi
Nba =	4.2	kips
Nag =	60.78	kips
phi_tc_pullout*Nag =	39.51	kips

Check Tensile Capacity vs. Tensile Load

Factored Tension Force, Nu =	0	kips
Nominal Tensile Resistance, Nr = min(phi_ts*Nsa, phi_tc*Ncb, phi_tc*Na) =	37.25	kips

Selected Anchor has Sufficient Tensile Capacity

Check Sustained Tensile Capacity vs. Sustained Tensile Load

Factored Sustained Tension Force, Nus =	0.00	kips
Nominal Tensile Resistance, Nr = 0.50*phi_tc_pullout*Nba =	21.98	kips

Selected Anchor has Sufficient Tensile Capacity

ADHESIVE ANCHOR SHEAR RESISTANCE:

Nominal Shear Resistance, Vr = phi_vs*0.6*Vsa <= phi_vc*Vcb <= phi_vp*Vcp

Phi Factors:

Steel Classification =	Ductile
Supplementary Reinforcement Included =	Yes
phi_vs =	0.65
phi_vc =	0.75
phi_vp =	0.75

Determine Nominal Steel Strength of Anchor in Shear, Vsa = Ase,V * f_uta:

Effective Cross-Sectional Area of Anchor in Tension, A_se,N:

Bar # =	override	#	5
Area, A_se,V =		0.307	inches^2

Tensile Strength of Anchor, futa <= 1.9*fy <= 125 ksi

fy =		60	ksi
fu =		90	ksi
1.9*fy =	override	114	ksi
Controlling Tensile Strenght, f_uta =		90	ksi
Vsa =		16.6	kips
phi_vs*Vsa =		10.77	kips

Determine Nominal Concrete Breakout Strength in Shear for a Single Anchor, Vcb = A_vc * Vb / (4.5*Ca1^2) * psi_ed,V * psi_c,V * psi_h,V * psi_p,V:

Psi Factors:

psi_ed,V [Modification factor for shear strength based on proximity to edges]			
Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =		5.25	inches
Minimum edge distance, Ca_min =	override	4	inches
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =		4	inches
Ca2 = Distance from C/L anchor to edge of concrete in direction perpendicular to Ca1 =		8	inches
Direction of Shear (perpendicular is conservative) =		Perpendicular	
psi_ed,V =		1.00	
psi_c,V [Modification factor for shear strength based on presence or absence of cracks and supplemental reinforcement]			
Where analysis shows no cracking at service loads, psi_c, V =		1.4	
Where analysis shows cracking at service loads and no supplemental rebar or edge rebar <#4, psi_c, V =		1.0	
Where analysis shows cracking at service loads and a #4 bar or greater between anchor and edge, psi_c, V =		1.2	
Where analysis shows cracking at service loads & >= #4 bar between edge & >=#4 stirrups spaced <=4", psi_c, V =		1.4	
psi_c,V =	override	1.2	
psi_h,V [Modification factor for shear strength of anchors located in members with ha < 1.5*Ca1]			
Concrete member thickness, ha =		9	inches
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =		4	inches
psi_h,V = max(sqrt(1.5*Ca1/ha),1.0) =		1.0	
psi_p,V [Modification factor for shear strength based on loading direction]			
psi_p,V =		1.00	

Projected Area of Concrete Failure Surface, Avc:

H = min(member depth, 1.5*Ca1) =	6	inches
S1 = min(Spacing/2,perpendicular edge distance(Ca2),1.5*edge distance(Ca1)) =	4	inches
S2 = min(Spacing/2,perpendicular edge distance,1.5*edge distance) =	4	inches
Avc = H(S1+S2) =	48.0	inches^2

Concrete Breakout Strength of a Single Anchor in Shear in Cracked Concrete, Vb:

le = hef < 8*dia. =	5	inches
diameter =	0.625	inches
f'c =	4000	psi
Ca1 =	4	inches
Vb = min[7*(le/dia)^0.2 * dia^0.5 * f'c^0.5 * Ca1^1.5 , 9 *f'c^0.5 * ca1^1.5]=	4.244	kips
Vcb =	3.40	kips
phi_vc*Vcb =	2.55	kips

Determine Nominal Concrete Breakout Strength in Shear for an Anchor Group, Vcbg = A_vc * Vb / (4.5*Ca1^2) * psi_ec,V * psi_ed,V * psi_c,V * psi_h,V * psi_p,V:

Psi Factors:

psi_ec,V [Modification factor for anchor group loaded eccentrically in shear]			
Eccentricity, e'V =		0.00	inches
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =		4	inches
psi_ec,V =		1.00	
psi_ed,V [Modification factor for shear strength based on proximity to edges]			
Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =		5.25	inches
Minimum edge distance, Ca_min =	override	4	inches
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =		4	inches
Ca2 = Distance from C/L anchor to edge of concrete in direction perpendicular to Ca1 =		8	inches
Direction of Shear (perpendicular is conservative) =		Perpendicular	
psi_ed,V =		1.00	
psi_c,V [Modification factor for shear strength based on presence or absence of cracks and supplemental reinforcement]			
Where analysis shows no cracking at service loads, psi_c, V =		1.4	
Where analysis shows cracking at service loads and no supplemental rebar or edge rebar <#4, psi_c, V =		1.0	
Where analysis shows cracking at service loads and a #4 bar or greater between anchor and edge, psi_c, V =		1.2	
Where analysis shows cracking at service loads & >= #4 bar between edge & >=#4 stirrups spaced <=4", psi_c, V =		1.4	
psi_c,V =	override	1.2	
psi_h,V [Modification factor for shear strength of anchors located in members with ha < 1.5*Ca1]			
Concrete member thickness, ha =		9	inches
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =		4	inches
psi_h,V = max(sqrt(1.5*Ca1/ha),1.0) =		1.0	
psi_p,V [Modification factor for shear strength based on loading direction]			
psi_p,V =		1.00	

Projected Area of Concrete Failure Surface, Avc:		
Avc = H(S1+S2) =	528.0	inches^2
Concrete Breakout Strength of a Single Anchor in Shear in Cracked Concrete, Vb:		
le = hef < 8*dia. =	5	inches
diameter =	0.625	inches
f'c =	4000	psi
Ca1 =	4	inches
Vb = min[7*(le/dia)^0.2 * dia^0.5 * f'c^0.5 * Ca1^1.5 , 9 *f'c^0.5 * ca1^1.5]=	4.24	kips
Vcb =	37.35	kips
phi_vc*Vcb = ACI Case 1, 1/2 load to front anchors - Capacity is double this	28.01	kips
Determine Nominal Concrete Pryout Strength for a Single Anchor, Vcp = Kcp*Ncp:		
Kcp = 1.0 for hef < 2.5" and 2.0 for hef >= 2.5" =	2	
Nominal Concrete Pryout Strength, Ncp = min(Na,Ncb)		
Na (from ACI Eq. 17.4.5.1a) =	3.78	kips
Ncb (from ACI Eq. 17.4.2.1a) =	4.22	kips
Nominal Concrete Pryout Strength, Ncp =	3.78	kips
Vcp =	7.57	kips
phi_vp*Vcp =	5.68	kips
Determine Nominal Concrete Pryout Strength for a Group of Anchors, Vcpg = Kcp*Ncpg:		
Kcp = 1.0 for hef < 2.5" and 2.0 for hef >= 2.5" =	2	
Nominal Concrete Pryout Strength, Ncpg = min(Nag,Ncbg)		
Nag (from ACI Eq. 17.4.5.1b) =	60.78	kips
Ncbg (from ACI Eq. 17.4.2.1b) =	57.31	kips
Nominal Concrete Pryout Strength, Ncpg =	57.31	kips
Vcp =	114.63	kips
phi_vp*Vcp =	85.97	kips
Check Shear Capacity vs. Shear Load		
Factored Shear Force, Vu =	0	kips
Nominal Shear Resistance, Vr = min(phi_vs*0.6*Vsa , phi_vc*Vcb, phi_vp*Vcp) =	28.01	kips
ACI Case 1, 1/2 load to front anchors - Total capacity is double this		

Selected Anchor has Sufficient Shear Capacity

SHEAR & TENSION INTERACTION ANALYSIS

Vu/(phi*Vn) =	0.00
Nu/(phi*Nn) =	0.00

For Vu/(phi*Vn) <=0.2: Nu <= phi*Nn
Interaction Capacity is Sufficient

For Nu/(phi*Nn) <=0.2: Vu <= phi * Vn
Interaction Capacity is Sufficient

For Vu/(phi*Vn) > 0.2 and Nu/(phi*Nn) > 0.2: Nu/(phi*Nn) + Vu/(phi*Vn) <=1.2
Not Applicable
Interaction Value = N/A

Project: *USH 2 over St. Louis River*	
Structure Number: *B-16-38*	**Project #:** *22114*
Task: *Parapet CIP Anchor Analysis - Median Parapets*	KL Engineering
Design By: *WAH* **Date:** *12/17/2024*	**Checked By:** *SKH* **Date:** *12/18/2024*

CONCRETE MASONRY CIP ANCHOR DESIGN PROGRAM

DESIGN LOADS: — Enter loads on single anchor or on group

Factored Tension Force, Nu =		1.00	kips
Factored Shear Force, Vu =		1.00	kips

ANCHOR PROPERTIES:

Proposed Anchor Size =		0.75	inches
Analyze as Single Anchor or Group =	Group Analysis Required	Group	
If Group, # of Anchors Effective in Tension =	10' width, all existing anchors - accounts for one side; For force in rebar or bolt only (not concrete)	16	anchors
If Group, # of Anchors Effective in Shear =	10' width, all existing anchors - accounts for two sides; For force in rebar or bolt only (not concrete)	32	anchors
Yield Strength of Anchor, fy =		60	ksi
Tensile Strength of Anchor, fut =		90	ksi
Condition of Concrete =			
Dry or Wet (Saturated) =		Saturated	
Cracked or Uncracked at Service Loads =		Cracked	
Compressive Strength =		4000	psi
Proposed Embedmen Depth =	OK, Below Limit of 20*Dia.	5	inches
Depth of Member =		9	inches

Single Anchor Edge Distance & Spacing: — Note: See ACI 17.4.2.3 when located near 3 or more edges

Minimum Edge Distance = 6*dia. =	ACI 17.7.2, if anchor will be torqued (ACI 20.6 if not)	4.5	inches
Minimum Spacing = 6*dia. =	ACI 17.7.2, if anchor will be torqued (4*dia. If not torqued)	4.5	inches
Left Side:			
Edge or Anchor =		Anchor	
Distance to Edge or Anchor Spacing =	OK, Meets Minimum Spacing Requirement	8	inches
Right Side:			
Edge or Anchor =		Anchor	
Distance to Edge or Anchor Spacing =	OK, Meets Minimum Spacing Requirement	8	inches
Front:			
Edge or Anchor =		Edge	
Distance to Edge or Anchor Spacing =	Warning, Minimum Edge Distance Not Met	3	inches
Back:			
Edge or Anchor =		Edge	
Distance to Edge or Anchor Spacing =	OK, Meets Minimum Edge Distance Requirement	90	inches

ANCHOR GEOMETRIC PROPERTIES:

Determine Projected Concrete Breakout Area of a Single Anchor, A_Nc:

A_Nco = 9 * hef^2 =	225.0	inches^2
S = min(1.5*hef, spacing/2, edge distance {ca})		
Left: S =	4	inches
Right: S =	4	inches
Front: S =	3	inches
Back: S =	7.5	inches
A_Nc =	84.0	inches^2

Calculate A_Nc per ACI Figure 17.4.2.1 for Anchor Group

1.5*hef =	7.5	inches
Width of Group =	135	inches
Depth of Group =	10.5	inches
A_Nc =	1417.5	inches^2

Calculate A_vc per ACI Figure 17.5.2.1b for Anchor Group override

Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =	3.00	inches
1.5*Ca1 =	4.50	inches
Member Depth, ha =	9.00	inches
Width of Group =	129	inches
Depth of Group =	4.50	inches
A_vc =	580.5	inches^2

CIP ANCHOR TENSILE RESISTANCE:

Nominal Tensile Resistance, Nr = phi_ts*Nsa <= phi_tc*Ncb <= phi_tc*Na

Phi Factors:

Steel Classification =		Ductile		*ACI 2.3*
Supplementary Reinforcement Included =		Yes		*ACI 17.3.3*
phi_ts =		0.75		
phi_tc =		0.75		
phi_tc_pullout =		0.75		

Determine Nominal Steel Strength of Anchor in Tension, Nsa = Ase,N * f_uta: *ACI 17.4.1.2*

Effective Cross-Sectional Area of Anchor in Tension, A_se,N:				
Anchor Size =	override	0.75	inches	
Area, A_se,N =	0.44	0.44	inches^2	
Tensile Strength of Anchor, futa <= 1.9*fy <= 125 ksi				
fy =		60	ksi	
fu =		90	ksi	
1.9*fy =	override	114	ksi	
Controlling Tensile Strenght, f_uta =		90	ksi	
Nsa =		39.6	kips	
phi_ts*Nsa =		29.7	kips	

Determine Nominal Concrete Breakout Strength of a Single Anchor in Tension, Ncb = A_nc * Nb / (9*hef^2) * psi_ed,N * psi_c,N * psi_cp,N: *ACI 17.4.2.1a*

Psi Factors:				
psi_ed,N [Modification factor for tensile strength based on proximity to edges]				*ACI 17.4.2.5*
Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =		5	inches	OK, <= 20*Dia.
Minimum edge distance, Ca_min =		3	inches	
psi_ed,N =		0.820		
psi_c,N [Modification factor for tensile strength based on presence or absence of cracks]				*ACI 17.4.2.6*
psi_c, N = (1.0 when cracking at service loads, 1.4 when no cracking at service loads) =		1.0		
psi_cp,N [Modification factor for post-installed anchors intended for use in uncracked concrete]				*ACI 17.4.2.7*
psi_cp,N =	Supplementary Reinforcement Included, Therefore =	1.0	for CIP anchors	
Concrete Breakout Strength of a Single Anchor in Tension in Cracked Concrete, Nb =		16.97	kips	*ACI 17.4.2.2*
Ncb =		5.20	kips	
phi_tc*Ncb =		3.90	kips	

Determine Nominal Concrete Breakout Strength of an Anchor Group in Tension, Ncbg = A_nc * Nb / (9*hef^2) *psi_ec,N* psi_ed,N * psi_c,N * psi_cp,N: *ACI 17.4.2.1b*

Psi Factors:				
psi_ec,N [Modification factor for anchor groups loaded eccentrically in tension]				*ACI 17.4.2.4*
Eccentricity, e'N =		0	inches	
psi_ec,N =		1.00		
psi_ed,N [Modification factor for tensile strength based on proximity to edges]				*ACI 17.4.2.5*
Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =		5	inches	OK, <= 20*Dia.
Minimum edge distance, Ca_min =		3	inches	
psi_ed,N =		0.820		
psi_c,N [Modification factor for tensile strength based on presence or absence of cracks]				*ACI 17.4.2.6*
psi_c, N = (1.0 when cracking at service loads, 1.4 when no cracking at service loads) =		1.0		
psi_cp,N [Modification factor for post-installed anchors intended for use in uncracked concrete]				*ACI 17.4.2.7*
psi_cp,N =	Supplementary Reinforcement Included, Therefore =	1.0	for CIP anchors	
Basic Concrete Breakout Strength of a Single Anchor in Tension in Cracked Concrete, Nb =	for normal weight concrete	17.0	kips	*ACI 17.4.2.2*
Ncbg =		87.67	kips	
phi_tc*Ncbg =		65.75	kips	

Determine Nominal Pullout Strength of a Single Anchor or Anchor Group in Tension, Npn = Np *psi_c,p: *ACI 17.4.3.1*

Psi Factors:				
psi_c,p [Modification factor for pull-out strength based on cracking]		1		*ACI 17.4.3.6*
Pullout Strength for a Single Anchor, Np = 8*Abrg*f'c =	conservative, not accounting for hooked ends	20.93	kips	
phi_tc_pullout*Nag for Single Anchor =		15.70	kips	
phi_tc_pullout*Nag for Anchor Group =		251.14	kips	

Determine Concrete Side Face Blowout of a Headed Single Anchor in Tension, Nsb = 160*Ca1*Abrg^0.5*lambda_a*f'c^0.5: *ACI 17.4.4.1*

Check Applicability: Applicable if hef > 2.5*Ca1:				
hef =		5	inches	
2.5*Ca1 =		3	inches	
Status of Applicability =		Not Applicable		
Side Face Blowout Strength for a Single Anchor, Nsb = 160*Ca1*Abrg^0.5*lambda_a*f'c^0.5 =		24.6	kips	
phi_tc_pullout*Nsb for Single Anchor =		18.41	kips	

Determine Concrete Side Face Blowout of Multiple Headed Anchors in Tension, Nsbg = (1+s/6/Ca1)*Nsb: *ACI 17.4.4.2*

Check Applicability: Applicable if hef > 2.5*Ca1 and anchor spacing < 6*Ca1:

hef = 5 inches
2.5*Ca1 = 7.5 inches
Spacing = 8 inches
6*Ca1 = 18 inches
Status of Applicability = Applicable

Side Face Blowout Strength for Multiple Achors, Nsbg = (1+2/6/Ca1)*Nsb = 35.5 kips
phi_tc_pullout*Nsbg for Multiple Anchors = 26.60 kips

Summary of Design Strengths for Tension:

Steel Strength, phi*Nsa = 475.2 kips
Concrete Breakout Strength, phi*Ncb = Controls 65.8 kips
Pullout Strength, phi*Npn = 251.1 kips
~~Sideface Blowout Strength, phi*Nsb = 26.6 kips~~

~~Controlling Tension Capacity = 26.6 kips~~

~~**Check Tensile Capacity vs. Tensile Load**~~
~~Factored Tension Force, Nu = 1.0 kips~~
~~Controlling Tension Capacity = 26.6 kips~~

~~Selected Anchor has Sufficient Tensile Capacity~~

CIP ANCHOR SHEAR RESISTANCE:

Nominal Shear Resistance, Vr = phi_vs*0.6*Vsa <= phi_vc*Vcb <= phi_vp*Vcp

Phi Factors:

Steel Classification = Ductile *ACI 2.3*
Supplementary Reinforcement Included = Yes *ACI 17.3.3*
phi_vs = 0.65
phi_vc = 0.75
phi_vp = 0.75

Determine Nominal Steel Strength of Anchor in Shear, Vsa = Ase,V * f_uta: *ACI 17.5.1.2*

Effective Cross-Sectional Area of Anchor in Tension, A_se,N:
Anchor Diameter = override 0.75 inches
Area, A_se,V = 0.334 inches^2
Tensile Strength of Anchor, futa <= 1.9*fy <= 125 ksi
fy = 60 ksi
fu = 90 ksi
1.9*fy = override 114 ksi
Controlling Tensile Strenght, f_uta = 90 ksi

Vsa = 18.0 kips
phi_vs*Vsa = 11.7 kips

Determine Nominal Concrete Breakout Strength in Shear for a Single Anchor, Vcb = A_vc * Vb / (4.5*Ca1^2) * psi_ed,V * psi_c,V * psi_h,V * psi_p,V: *ACI 17.5.2.1a*

Psi Factors:

psi_ed,V [Modification factor for shear strength based on proximity to edges] *ACI 17.5.2.6*
Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter = 5 inches OK, <= 20*Dia.
Minimum edge distance, Ca_min = override 3 inches
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear = 3 inches
Ca2 = Distance from C/L anchor to edge of concrete in direction perpendicular to Ca1 = 8 inches
Direction of Shear (perpendicular is conservative) = Perpendicular

psi_ed,V = 1.0

psi_c,V [Modification factor for shear strength based on presence or absence of cracks and supplemental reinforcement] *ACI 17.5.2.7*
Where analysis shows no cracking at service loads, psi_c, V = 1.4
Where analysis shows cracking at service loads and no supplemental rebar or edge rebar <#4, psi_c, V = 1.0
Where analysis shows cracking at service loads and a #4 bar or greater between anchor and edge, psi_c, V = 1.2
Where analysis shows cracking at service loads & >= #4 bar between edge & >=#4 stirrups spaced <=4", psi_c, V = 1.4
override
psi_c,V = 1.2

psi_h,V [Modification factor for shear strength of anchors located in members with ha < 1.5*Ca1] *ACI 17.5.2.8*
Concrete member thickness, ha = 9 inches
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear = 3 inches

psi_h,V = max(sqrt(1.5*Ca1/ha),1.0) = 1.0

psi_p,V [Modification factor for shear strength based on loading direction] *ACI 17.5*
psi_p,V = 1.00

Projected Area of Concrete Failure Surface, Avc:
H = min(member depth, 1.5*Ca1) = 4.5 inches
S1 = min(Spacing/2,perpendicular edge distance(Ca2),1.5*edge distance(Ca1)) = 4 inches
S2 = min(Spacing/2,perpendicular edge distance,1.5*edge distance) = 4 inches

Avc = H(S1+S2) = 36.0 inches^2

Concrete Breakout Strength of a Single Anchor in Shear in Cracked Concrete, Vb:			*ACI 17.5.2.2*
le = hef < 8*dia. =	5	inches	
diameter =	0.75	inches	
f'c =	4000	psi	
Ca1 =	3	inches	
Vb = min[7*(le/dia)^0.2 * dia^0.5 * f'c^0.5 * Ca1^1.5 , 9 *f'c^0.5 * ca1^1.5]=	2.912	kips	
Vcb =	3.11	kips	
phi_vc*Vcb =	2.33	kips	
Determine Nominal Concrete Breakout Strength in Shear for an Anchor Group, Vcbg = A_vc * Vb / (4.5*Ca1^2) * psi_ec,V * psi_ed,V * psi_c,V * psi_h,V * psi_p,V:			*ACI 17.5.2.1b*
Psi Factors:			
psi_ec,V [Modification factor for anchor group loaded eccentrically in shear]			*ACI 17.5.2.5*
Eccentricity, e'V =	0	inches	
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =	3	inches	
psi_ec,V =	1.00		
psi_ed,V [Modification factor for shear strength based on proximity to edges]			*ACI 17.5.2.6*
Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =	5	inches	Warning, Exceeds 20*Dia.
Minimum edge distance, Ca_min = (override)	3	inches	
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =	3	inches	
Ca2 = Distance from C/L anchor to edge of concrete in direction perpendicular to Ca1 =	8	inches	
Direction of Shear (perpendicular is conservative) =	Perpendicular		
psi_ed,V =	1.00		
psi_c,V [Modification factor for shear strength based on presence or absence of cracks and supplemental reinforcement]			*ACI 17.5.2.7*
Where analysis shows no cracking at service loads, psi_c, V =	1.4		
Where analysis shows cracking at service loads and no supplemental rebar or edge rebar <#4, psi_c, V =	1.0		
Where analysis shows cracking at service loads and a #4 bar or greater between anchor and edge, psi_c, V =	1.2		
Where analysis shows cracking at service loads & >= #4 bar between edge & >=#4 stirrups spaced <=4", psi_c, V =	1.4		
psi_c,V = (override)	1.2		
psi_h,V [Modification factor for shear strength of anchors located in members with ha < 1.5*Ca1]			*ACI 17.5.2.8*
Concrete member thickness, ha =	9	inches	
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =	3	inches	
psi_h,V = max(sqrt(1.5*Ca1/ha),1.0) =	1.0		
psi_p,V [Modification factor for shear strength based on loading direction]			*ACI 17.5*
psi_p,V =	1.00		
Projected Area of Concrete Failure Surface, Avc:			
Avc = H(S1+S2) =	580.5	inches^2	
Concrete Breakout Strength of a Single Anchor in Shear in Cracked Concrete, Vb:			*ACI 17.5.2.2*
le = hef < 8*dia. =	5	inches	
diameter =	0.75	inches	
f'c =	4000	psi	
Ca1 =	3	inches	
Vb = min[7*(le/dia)^0.2 * dia^0.5 * f'c^0.5 * Ca1^1.5 , 9 *f'c^0.5 * ca1^1.5]=	2.91	kips	
Vcb =	50.08	kips	
phi_vc*Vcb =	37.56	kips	
Determine Nominal Concrete Pryout Strength for a Single Anchor, Vcp = Kcp*Ncp:			*ACI 17.5.3.1(a)*
Kcp = 1.0 for hef < 2.5" and 2.0 for hef >= 2.5" =	2		
Nominal Concrete Pryout Strength, Ncp = Ncb for cast in place anchors =	5.20	kips	
Vcp =	10.39	kips	
phi_vp*Vcp =	7.79	kips	
~~**Determine Nominal Concrete Pryout Strength for a Group of Anchors, Vcpg = Kcp*Ncpg:**~~			~~*ACI 17.5.3.1(b)*~~
~~Kcp = 1.0 for hef < 2.5" and 2.0 for hef >= 2.5" =~~	~~2~~		
~~Nominal Concrete Pryout Strength, Ncpg = Ncbg for cast in place anchors =~~	~~87.67~~	~~kips~~	
~~Vcp =~~	~~175.34~~	~~kips~~	
~~phi_vp*Vcp =~~	~~131.50~~	~~kips~~	
Summary of Design Strengths for Shear:			
Steel Strength, phi*Vsa =	375.1	kips	
Concrete Breakout Strength, phi*Vcb =	37.6	kips	
Pryout Strength, phi*Vcp =	131.5	kips	
Controlling Shear Capacity =	37.6	kips	

Check Shear Capacity vs. Shear Load

Factored Shear Force, Vu =	1.00 kips
Controlling Shear Capacity =	37.56 kips

Selected Anchor has Sufficient Shear Capacity

SHEAR & TENSION INTERACTION ANALYSIS **ACI 17.6**

Vu/(phi*Vn) =	0.03
Nu/(phi*Nn) =	0.04

For Vu/(phi*Vn) <=0.2: Nu <= phi*Nn
Interaction Capacity is Sufficient

For Nu/(phi*Nn) <=0.2: Vu <= phi * Vn
Interaction Capacity is Sufficient

For Vu/(phi*Vn) > 0.2 and Nu/(phi*Nn) > 0.2: Nu/(phi*Nn) + Vu/(phi*Vn) <=1.2
Not Applicable
Interaction Value = N/A

Project: *USH 2 over St. Louis River*			
Structure Number: *B-16-38*		**Project #:** *22114*	
Task: *Median Parapet Analysis*			
Design By: *WAH*	**Date:** *12/17/2024*	**Checked By:** *SKH*	**Date:** *12/18/2024*

KL Engineering

PARAPET ANALYSIS

DESIGN PARAMETERS:

Parapet Parameters:

Railing Design Level Designation		TL-4	
Height of Parapet =		32	inches
Width of Parapet at Base =		1.58	feet
Transverse Load on Barrier, Ft (LRFD T.A13.2.1) =		54.0	kips
Longitudinal Length of distribution of impact force, Lt (LRFD T. A13.2.1) =		3.5	feet

Material Parameters:

Compressive Strength of Moment Slab, f'c =		3,500	psi
Yield Strength of Steel, fy =		60,000	psi

WIND LOADING

From AASHTO LRFD 9th Edition:

Equation 3.8.1.2.1-1: Pz = 0.00256*V^2*Kz*G*Cd

Service I: Design 3-second gust wind speed, V =		Table 3.8.1.1.2-1	70	mph
Strength III: Design 3-second gust wind speed, V =		Table 3.8.1.1.2-1	115	mph
Strength V: Design 3-second gust wind speed, V =		Figure 3.8.1.1.2-1	80	mph
Exposure Category =		3.8.1.1.5	D	
Pressure exposure and elevation coefficient,Kz =	150' above grade, conservative	Table C3.8.1.2.1-1	1.52	
Gust effect factor,G =		Table 3.8.1.2.1-1	1.00	
Drag Coefficient, Cd =		Table 3.8.1.2.1-2	1.00	
Service I: Pz = 0.00256*V^2*Kz*G*Cd =			19.1	psf
Strength III: Pz = 0.00256*V^2*Kz*G*Cd =			51.5	psf
Strength V: Pz = 0.00256*V^2*Kz*G*Cd =			24.9	psf

From AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals

Equation 3.8.1-1: Pz = 0.00256*Kz*Kd*G*V^2*Cd

1700-Year MRI Basic Wind Speed, V =		Fig. 3.8-2b	120	mph
Pressure exposure and elevation coefficient,Kz =	150' above grade, conservative	Table C3.8.4-1	1.37	
Directionality Factor, Kd =		Table C3.8.5-1	0.95	
Gust effect factor,G =		3.8.6	1.14	
Drag Coefficient, Cd =		Table 3.8.7-1	0.50	
Pz = 0.00256KzKdG*V^2*Cd =			27.3	psf

Loading on Parapet

Light Pole Diameter =	average equivalent width to account for arms & pole taper	0.57	feet
Light Pole Height =		37.33	feet
Parapet Height =		2.67	feet
Parapet Width at Base =		1.58	feet
Horizontal Load on Light Pole =			
Service I =		0.406	kips
Strength III =		1.095	kips
Strength V =		0.530	kips
Per LRFD Signs, Luminaires, and Traffic Signals Spec =		0.582	kips
Horizontal Load on Parapet =			
Service I =		0.051	kips/foot
Strength III =		0.137	kips/foot
Strength V =		0.066	kips/foot
Per LRFD Signs, Luminaires, and Traffic Signals Spec =		0.073	kips/foot
Distribution of Light Pole Load to Base of Parapet			
Width of Anchor Bolts =		0.83	feet
45 degree distribution to base of parapet =		6.166	feet
Horizontal Load at Base of Parapet =			
Service I =		0.117	kips/foot
Strength III =		0.315	kips/foot
Strength V =		0.152	kips/foot
Per LRFD Signs, Luminaires, and Traffic Signals Spec =	Strength III pressure on parapet, Guide Spec on Light Pole	0.315	kips/foot

Moment at Base of Parapet =			
Service I =		1.47	kips/foot
Strength III =		3.97	kips/foot
Strength V =		1.92	kips/foot
Per LRFD Signs, Luminaires, and Traffic Signals Spec =	Strength III pressure on parapet, Guide Spec on Light Pole	2.20	kips/foot

Reinforcement			
Adhesive Anchor Tensile Capacity in Cracked Concrete =		3.73	kips/foot
Adhesive Anchor Tensile Capacity in Uncracked Concrete =		4.91	kips/foot
CIP Anchor Tensile Capacity in Cracked Concrete (existing reinforcement) =		6.58	kips/foot
CIP Anchor Tensile Capacity in Uncracked Concrete (existing reinforcement) =		9.21	kips/foot
Percentage of Adhesive Anchor Tensile Capacity in Cracked Concrete =		25%	
Percentage of Adhesive Anchor Tensile Capacity in Uncracked Concrete =		25%	
Percentage of CIP Anchor Tensile Capacity in Cracked Concrete (existing reinforcement) =		25%	
Percentage of CIP Anchor Tensile Capacity in Uncracked Concrete (existing reinforcement) =		25%	
Average Tensile Capacity of Anchors =		6.11	kips/foot
Bar Size =		#	5
Bar Spacing =	modified to provide a tension equal to the anchor capacity	36.15	inches
Total Area of Steel =	override	0.10	inches^2/foot
'd' = thickness of design section - 2.0" cover - bar size/16 =	16.00	16.00	inches

Check Moment Capacity:			
C = T = as*fy =	set equal to average tensile capacity of anchors	6.11	kips/foot
B1 = 0.85-0.05(f'c - 4000)/1000 <0.85 =		0.85	
a = C/bB1f'c =		0.17	inches
c = a / β_1 =		0.201	inches
ε_{bot} = 0.003 [(d_s / c) -1)]		0.235	inches/inch
ϕ_f =	*Tension Controlled*	0.900	
Mr = (phi)Mn = (phi)T(d-a/2)		7.29	foot-kips/foot
Mu =		3.97	foot-kips/foot

OK, Section Capacity is Sufficient

Check Reinforcement Limit per AASHTO 5.6.2.1-1	
c/de =	0.01
Limit (to ensure steel yield before concrete crushing) =	0.60

OK, Section is Not Over-Reinforced

Minimum reinforcement check (AASHTO 5.6.3.3):

phi(Mn) > 1.072 Mcr

Determine Mcr

Modulus of Rupture, fr = .24 (f'c)^0.5 =	0.449	ksi
Section Modulus, Sc =	721.70	$inches^3$
Mcr = Sc*fr =	27.00	foot-kips
Mstrength1 =	3.97	foot-kips
1.072Mcr =	28.95	foot-kips
1.33*Mstrength1	5.28	foot-kips
Mr	7.29	foot-kips
min(1.072Mcr,1.33Mstrength1)	5.28	foot-kips

Min. Reinforcement Criteria is Satisfied

Check Shear Capacity (LRFD 5.8.3.3):

Determine dv:

dv1 = d - a/2 =	15.91	inches
dv2 = 0.9*d =	14.40	inches
dv3 = 0.72 * member height =	13.68	inches
dv = max(dv1, dv2, dv3) =	15.91	inches

Nominal Shear Resistance:

Vn1 = Vc = 0.0316*β*γ*f'c^0.5*bv*dv =	22.58	kips
Vn2 = 0.25*f'c*b*dv =	167.10	kips
Vn = min(Vn1,Vn2) =	22.58	kips
ϕv =	0.90	
Vr = (phi)Vn =	20.32	kips
Vu =	0.31	kips

OK, Section Capacity is Sufficient

DETERMINE BARRIER CAPACITY FOR EXTREME EVENT LOAD (LRFD A13.3.1):

Flexural resistance of cantilevered parapet about an axis parallel to the longitudinal axis of the bridge, Mc:

Vertical reinforcement bar size =			#	5
Vertical reinforcement bar spacing =			8	inches
Average parapet thickness =		min. width at base	19.00	inches
Total Area of Steel =	override		0.47	inches^2/foot
'd' = thickness of design section - cover - bar size/16 =	16.00		16.00	inches
Resistance Factor, phi (AASHTO 5.5.4.2) =			0.75	

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Section Capacity, Mn = T(d-a/2)	override		
C = T = as*fy =	3.75	3.75	kips/foot
h = 'd' =	based on #5 anchors only	16.00	inches
B1 = 0.85-0.05(f'c - 4000)/1000 <0.85 =		0.85	
a = C/bB1f'c =		0.11	inches
Mc = Mr = (phi)Mn =		3.74	foot-kips/foot

Flexural resistance of cantilevered parapet about vertical axis, Mw:

Horizontal reinforcement bar size =	#	4
Number of bars at front or back face =	5	bars
Average parapet thickness =	19.0	inches
Total Area of Steel =	0.98	inches^2/foot
'd' = thickness of design section - cover - bar size/16 =	16.12	inches
phi (AASHTO 1.3.2 for extreme event limit state) =	1.0	

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Section Capacity, Mn = T(d-a/2)		
C = T = as*fy =	58.90	kips/foot
h = 'd' =	16.12	inches
B1 = 0.85-0.05(f'c - 4000)/1000 <0.85 =	0.85	
a = C/bB1f'c =	1.65	inches
Mw = Mr = (phi)Mn =	75.08	foot-kips/foot

Nominal resistance to transverse load, Rw: Note, calcs are for impacts w/in segment, not at ends

Additional flexural resistance at top of wall, Mb =	0.0	foot-kips
Longitudinal Length of distribution of impact force, Lt (LRFD T. A13.2.1) =	3.5	feet
Height of Parapet, H =	2.67	feet
Critical length of yield line, Lc (LRFD A13.3.1-2) =	22.53	feet
Resistance, Rw (LRFD A13.3.1-1) =	63.14	kips
Transverse Load, Ft (LRFD T.A13.2.1) =	54.0	kips

Status = *Sufficient Capacity is Provided*

Project: *USH 2 over St. Louis River*

Structure Number: *B-16-38* **Project #:** *22114*

Task: *Parapet Adhesive Anchor Analysis - Exterior Parapets*

Design By: *WAH* **Date:** *12/17/2024* **Checked By:** *SKH* **Date:** *12/18/2024*

KL Engineering

CONCRETE MASONRY ADHESIVE ANCHOR DESIGN PROGRAM

DESIGN LOADS: Enter loads on single a

Factored Tension Force, Nu =		0
Continuous Factored Tension Force, Nus {from loads that are always present} =		0
Factored Shear Force, Vu =		0

ANCHOR PROPERTIES:

Proposed Bar Size =			#
Analyze as Single Anchor or Group =		Group Analysis Required	Group
If Group, # of Anchors Effective in Tension =	10' width, all new anchors - accounts for one side	For force in rebar or bolt only (not concrete)	14
If Group, # of Anchors Effective in Shear =	10' width, all new anchors - accounts for two sides	For force in rebar or bolt only (not concrete)	28
Condition of Concrete =			
Dry or Wet (Saturated) =			Saturated
Cracked or Uncracked at Service Loads =			Cracked
Compressive Strength =			4000
Proposed Embedmen Depth =		OK, Below Limit of 20*Dia.	5.25
Depth of Member =			9.00

<u>Single Anchor Edge Distance & Spacing:</u> Note: See ACI 17.4.2.3 when located near 3 or more edges

Minimum Edge Distance = 6*dia. =			3.75
Minimum Spacing = 6*dia. =			3.75
Left Side:			
Edge or Anchor =			Anchor
Distance to Edge or Anchor Spacing =		OK, Meets Minimum Spacing Requirement	9.00
Right Side:			
Edge or Anchor =			Anchor
Distance to Edge or Anchor Spacing =		OK, Meets Minimum Spacing Requirement	9.00
Front:			
Edge or Anchor =			Edge
Distance to Edge or Anchor Spacing =	back anchor only in tension	OK, Meets Minimum Edge Distance Requirement	11.00
Back:			
Edge or Anchor =			Edge
Distance to Edge or Anchor Spacing =		OK, Meets Minimum Edge Distance Requirement	90.00

ANCHOR GEOMETRIC PROPERTIES:

Determine Projected Concrete Breakout Area of a Single Adhesive Anchor, A_Nc:

S = min(1.5*hef, spacing/2, edge distance {ca})

Left: S =	4.5
Right: S =	4.5
Front: S =	7.875
Back: S =	7.875
A_Nc =	141.8

Calculate A_Nc per ACI Figure 17.4.2.1 for Anchor Group

1.5*hef =	7.875	inches
Width of Group =	132.75	inches
Depth of Group =	18.88	inches

A_Nc = 2505.7

Determine Projected Influence Area of a Single Adhesive Anchor, A_Na:

S = min(C_Na, spacing/2, edge distance {ca})

tau_uncr =	510
C_Na = 10 * Dia. * (tau_uncr/1100)^0.5 =	4.26
Left: S =	4.26
Right: S =	4.26
Front: S =	4.26
Back: S =	4.26
A_Na =	72.4

Calculate A_Na per ACI Figure 17.4.5.1 for Anchor Group

C_Na = 10 * Dia. * (tau_uncr/1100)^0.5 =		4.26	inches
Width of Group =		125.51	inches
Depth of Group =		15.26	inches
A_Na =			1914.8

Calculate A_vc per ACI Figure 17.5.2.1b for Anchor Group

	override			
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =	4.00	4.00	inches	ACI Case 1, 1/2 load tc
1.5*Ca1 =		6.00	inches	
Member Depth, ha =		9.00	inches	
Width of Group =		129.00	inches	
Depth of Group =		4.00	inches	
A_vc =				516.0

ADHESIVE ANCHOR TENSILE RESISTANCE:

Nominal Tensile Resistance, Nr = phi_ts*Nsa <= phi_tc*Ncb <= phi_tc*Na

Phi Factors:

Steel Classification =	Ductile	
Supplementary Reinforcement Included =	Yes	
phi_ts =	0.75	
phi_tc =	0.65	
phi_tc_pullout =	0.65	

Determine Nominal Steel Strength of Anchor in Tension, Nsa = Ase,N * f_uta:

Effective Cross-Sectional Area of Anchor in Tension, A_se,N:			
Bar # =	override	# 5	
Area, A_se,N =		0.31	inches^2
Tensile Strength of Anchor, futa <= 1.9*fy <= 125 ksi			
fy =		60	ksi
fu =		90	ksi
1.9*fy =	override	114	ksi
Controlling Tensile Strenght, f_uta =		90	ksi
Nsa =		27.6	kips
phi_ts*Nsa =		20.7	kips

Determine Nominal Concrete Breakout Strength of a Single Anchor in Tension, Ncb = A_nc * Nb / (9*hef^2) * psi_ed,N * psi_c,N * psi_cp,N:

Psi Factors:			
psi_ed,N [Modification factor for tensile strength based on proximity to edges]			
Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =		5.25	inches
Minimum edge distance, Ca_min =		11	inches
psi_ed,N =		1.000	
psi_c,N [Modification factor for tensile strength based on presence or absence of cracks]			
psi_c, N = (1.0 when cracking at service loads, 1.4 when no cracking at service loads) =		1.0	
psi_cp,N [Modification factor for post-installed anchors intended for use in uncracked concrete]			
Critical Edge Distance, Cac = 2*hef =		10.5	inches
psi_cp,N =	Supplementary Reinforcement Included, Therefore =	1.000	
Concrete Breakout Strength of a Single Anchor in Tension in Cracked Concrete, Nb =		12.93	kips
Ncb =		7.39	kips
phi_tc*Ncb =		4.80	kips

Determine Nominal Concrete Breakout Strength of an Anchor Group in Tension, Ncbg = A_nc * Nb / (9*hef^2) *psi_ec,N* psi_ed,N * psi_c,N * psi_cp,N:

Psi Factors:			
psi_ec,N [Modification factor for anchor groups loaded eccentrically in tension]			
Eccentricity, e'N =		0.00	inches
psi_ec,N =		1.00	
psi_ed,N [Modification factor for tensile strength based on proximity to edges]			
Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =		5.25	inches
Minimum edge distance, Ca_min =		11	inches
psi_ed,N =		1.000	
psi_c,N [Modification factor for tensile strength based on presence or absence of cracks]			
psi_c, N = (1.0 when cracking at service loads, 1.4 when no cracking at service loads) =		1.0	
psi_cp,N [Modification factor for post-installed anchors intended for use in uncracked concrete]			
Critical Edge Distance, Cac = 2*hef =		10.5	inches
psi_cp,N =	Supplementary Reinforcement Included, Therefore =	1.000	
Basic Concrete Breakout Strength of a Single Anchor in Tension in Cracked Concrete, Nb =	for normal weight concrete	10.3	kips
Ncbg =		104.51	kips
phi_tc*Ncbg =		67.93	kips

Determine Nominal Bond Strength of a Single Anchor in Tension, Na = A_na * Nba / (4*C_na^2) * psi_ed,Na * psi_cp,Na:

Psi Factors:

psi_ed,Na [Modification factor for tensile strength of adhesive anchors based on proximity to edges]

Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter = 5.25 inches
Minimum edge distance, Ca_min = 11 inches
C_Na = distance required to develop full bond strength = 4.26 inches
psi_ed,Na = 1.000

psi_cp,Na [Modification factor for pull-out strength of adhesive anchors]

Critical Edge Distance, Cac = 2*hef = 10.5 inches
psi_cp,Na = Supplementary Reinforcement Included, Therefore = 1.00

Bond Strength in Tension of a Single Adhesive Anchor, Nba = tau_cr * pi * dia. * hef:

tau = 410 psi
Nba = 4.2 kips

Na = 4.23 kips
phi_tc_pullout*Na = 2.75 kips

Determine Nominal Bond Strength of an Anchor Group in Tension, Nag = A_na * Nba / (4*C_na^2) *psi_ec,Na* psi_ed,Na * psi_cp,Na:

Psi Factors:

psi_ec,N [Modification factor for anchor groups loaded eccentrically in tension]

Eccentricity, e'N = 0 inches
psi_ec,N = 1.00

psi_ed,Na [Modification factor for tensile strength of adhesive anchors based on proximity to edges]

Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter = 5.25 inches
Minimum edge distance, Ca_min = 11 inches
C_Na = distance required to develop full bond strength = 4.26 inches
psi_ed,Na = 1.000

psi_cp,Na [Modification factor for pull-out strength of adhesive anchors]

Critical Edge Distance, Cac = 2*hef = 10.5 inches
psi_cp,Na = Supplementary Reinforcement Included, Therefore = 1.00

Bond Strength in Tension of a Single Adhesive Anchor, Nba = tau_cr * pi * dia. * hef:

tau = 410 psi
Nba = 4.2 kips

Nag = 111.71 kips
phi_tc_pullout*Nag = 72.61 kips

Check Tensile Capacity vs. Tensile Load

Factored Tension Force, Nu = 0 kips
Nominal Tensile Resistance, Nr = min(phi_ts*Nsa, phi_tc*Ncb, phi_tc*Na) = 67.93 kips

Selected Anchor has Sufficient Tensile Capacity

Check Sustained Tensile Capacity vs. Sustained Tensile Load

Factored Sustained Tension Force, Nus = 0.00 kips
Nominal Tensile Resistance, Nr = 0.50*phi_tc_pullout*Nba = 19.23 kips

Selected Anchor has Sufficient Tensile Capacity

ADHESIVE ANCHOR SHEAR RESISTANCE:

Nominal Shear Resistance, Vr = phi_vs*0.6*Vsa <= phi_vc*Vcb <= phi_vp*Vcp

Phi Factors:

Steel Classification = Ductile
Supplementary Reinforcement Included = Yes
phi_vs = 0.65
phi_vc = 0.75
phi_vp = 0.75

Determine Nominal Steel Strength of Anchor in Shear, Vsa = Ase,V * f_uta:

Effective Cross-Sectional Area of Anchor in Tension, A_se,N:

Bar # = override # 5
Area, A_se,V = 0.307 inches^2

Tensile Strength of Anchor, futa <= 1.9*fy <= 125 ksi

fy = 60 ksi
fu = 90 ksi
1.9*fy = override 114 ksi
Controlling Tensile Strenght, f_uta = 90 ksi

Vsa = 16.6 kips
phi_vs*Vsa = 10.77 kips

Determine Nominal Concrete Breakout Strength in Shear for a Single Anchor, Vcb = A_vc * Vb / (4.5*Ca1^2) * psi_ed,V * psi_c,V * psi_h,V * psi_p,V:

Psi Factors:

psi_ed,V [Modification factor for shear strength based on proximity to edges]

Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =	override	5.25	inches
Minimum edge distance, Ca_min =	4.00	4	inches
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =	4.00	4	inches
Ca2 = Distance from C/L anchor to edge of concrete in direction perpendicular to Ca1 =		9	inches
Direction of Shear (perpendicular is conservative) =		Perpendicular	
psi_ed,V =		1.00	

psi_c,V [Modification factor for shear strength based on presence or absence of cracks and supplemental reinforcement]

Where analysis shows no cracking at service loads, psi_c, V =		1.4
Where analysis shows cracking at service loads and no supplemental rebar or edge rebar <#4, psi_c, V =		1.0
Where analysis shows cracking at service loads and a #4 bar or greater between anchor and edge, psi_c, V =		1.2
Where analysis shows cracking at service loads & >= #4 bar between edge & >=#4 stirrups spaced <=4", psi_c, V =		1.4
	override	
psi_c,V =		1.2

psi_h,V [Modification factor for shear strength of anchors located in members with ha < 1.5*Ca1]

Concrete member thickness, ha =	9	inches
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =	4	inches
psi_h,V = max(sqrt(1.5*Ca1/ha),1.0) =	1.0	

psi_p,V [Modification factor for shear strength based on loading direction]

psi_p,V =	1.00

Projected Area of Concrete Failure Surface, Avc:

H = min(member depth, 1.5*Ca1) =	6	inches
S1 = min(Spacing/2,perpendicular edge distance(Ca2),1.5*edge distance(Ca1)) =	4.5	inches
S2 = min(Spacing/2,perpendicular edge distance,1.5*edge distance) =	4.5	inches
Avc = H(S1+S2) =	54.0	inches^2

Concrete Breakout Strength of a Single Anchor in Shear in Cracked Concrete, Vb:

le = hef < 8*dia. =	5	inches
diameter =	0.625	inches
f'c =	4000	psi
Ca1 =	4	inches
Vb = min[7*(le/dia)^0.2 * dia^0.5 * f'c^0.5 * Ca1^1.5 , 9 *f'c^0.5 * ca1^1.5]=	4.244	kips

Vcb =	3.82	kips
phi_vc*Vcb =	2.86	kips

Determine Nominal Concrete Breakout Strength in Shear for an Anchor Group, Vcbg = A_vc * Vb / (4.5*Ca1^2) * psi_ec,V * psi_ed,V * psi_c,V * psi_h,V * psi_p,V:

Psi Factors:

psi_ec,V [Modification factor for anchor group loaded eccentrically in shear]

Eccentricity, e'V =	0.00	inches
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =	4	inches
psi_ec,V =	1.00	

psi_ed,V [Modification factor for shear strength based on proximity to edges]

Effective Embedment Depth of Anchor, hef <= 20 * anchor diameter =	override	5.25	inches
Minimum edge distance, Ca_min =	4.00	4	inches
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =	4.00	4	inches
Ca2 = Distance from C/L anchor to edge of concrete in direction perpendicular to Ca1 =		9	inches
Direction of Shear (perpendicular is conservative) =		Perpendicular	
psi_ed,V =		1.00	

psi_c,V [Modification factor for shear strength based on presence or absence of cracks and supplemental reinforcement]

Where analysis shows no cracking at service loads, psi_c, V =		1.4
Where analysis shows cracking at service loads and no supplemental rebar or edge rebar <#4, psi_c, V =		1.0
Where analysis shows cracking at service loads and a #4 bar or greater between anchor and edge, psi_c, V =		1.2
Where analysis shows cracking at service loads & >= #4 bar between edge & >=#4 stirrups spaced <=4", psi_c, V =		1.4
	override	
psi_c,V =		1.2

psi_h,V [Modification factor for shear strength of anchors located in members with ha < 1.5*Ca1]

Concrete member thickness, ha =	9	inches
Ca1 = Distance from C/L anchor to edge of concrete in direction of applied shear =	4	inches
psi_h,V = max(sqrt(1.5*Ca1/ha),1.0) =	1.0	

psi_p,V [Modification factor for shear strength based on loading direction]

psi_p,V =	1.00

Projected Area of Concrete Failure Surface, Avc:
Avc = H(S1+S2) = 516.0 inches^2

Concrete Breakout Strength of a Single Anchor in Shear in Cracked Concrete, Vb:

le = hef < 8*dia. =	5	inches
diameter =	0.625	inches
f'c =	4000	psi
Ca1 =	4	inches

Vb = min[7*(le/dia)^0.2 * dia^0.5 * f'c^0.5 * Ca1^1.5 , 9 *f'c^0.5 * ca1^1.5]= 4.24 kips

Vcb =		36.50	kips
phi_vc*Vcb =	ACI Case 1, 1/2 load to front anchors - Capacity is double this	27.37	kips

Determine Nominal Concrete Pryout Strength for a Single Anchor, Vcp = Kcp*Ncp:

Kcp = 1.0 for hef < 2.5" and 2.0 for hef >= 2.5" =	2	
Nominal Concrete Pryout Strength, Ncp = min(Na,Ncb)		
Na (from ACI Eq. 17.4.5.1a) =	4.23	kips
Ncb (from ACI Eq. 17.4.2.1a) =	7.39	kips
Nominal Concrete Pryout Strength, Ncp =	4.23	kips
Vcp =	8.45	kips
phi_vp*Vcp =	6.34	kips

Determine Nominal Concrete Pryout Strength for a Group of Anchors, Vcpg = Kcp*Ncpg:

Kcp = 1.0 for hef < 2.5" and 2.0 for hef >= 2.5" =	2	
Nominal Concrete Pryout Strength, Ncpg = min(Nag,Ncbg)		
Nag (from ACI Eq. 17.4.5.1b) =	111.71	kips
Ncbg (from ACI Eq. 17.4.2.1b) =	104.51	kips
Nominal Concrete Pryout Strength, Ncpg =	104.51	kips
Vcp =	209.02	kips
phi_vp*Vcp =	156.77	kips

Check Shear Capacity vs. Shear Load

Factored Shear Force, Vu =	0	kips
Nominal Shear Resistance, Vr = min(phi_vs*0.6*Vsa , phi_vc*Vcb, phi_vp*Vcp) =	27.37	kips

ACI Case 1, 1/2 load to front anchors - Total capacity is double this

Selected Anchor has Sufficient Shear Capacity

SHEAR & TENSION INTERACTION ANALYSIS

Vu/(phi*Vn) =	0.00
Nu/(phi*Nn) =	0.00

For Vu/(phi*Vn) <=0.2: Nu <= phi*Nn
Interaction Capacity is Sufficient

For Nu/(phi*Nn) <=0.2: Vu <= phi * Vn
Interaction Capacity is Sufficient

For Vu/(phi*Vn) > 0.2 and Nu/(phi*Nn) > 0.2: Nu/(phi*Nn) + Vu/(phi*Vn) <=1.2
Not Applicable
Interaction Value = N/A

Project: *USH 2 over St. Louis River*			
Structure Number: *B-16-38*	**Project #:** *22114*		
Task: *Exterior Parapet Analysis*			KL Engineering
Design By: *WAH*	**Date:** *12/17/2024*	**Checked By:** *SKH*	**Date:** *12/18/2024*

PARAPET ANALYSIS

DESIGN PARAMETERS:

Parapet Parameters:

Railing Design Level Designation		TL-4	
Height of Parapet =		32	inches
Width of Parapet at Base =		1.25	feet
Transverse Load on Barrier, Ft (LRFD T.A13.2.1) =		54.0	kips
Longitudinal Length of distribution of impact force, Lt (LRFD T. A13.2.1) =		3.5	feet

Material Parameters:

Compressive Strength of Moment Slab, f'c =		3,500	psi
Yield Strength of Steel, fy =		60,000	psi

DETERMINE BARRIER CAPACITY FOR EXTREME EVENT LOAD (LRFD A13.3.1):

Flexural resistance of cantilevered parapet about an axis parallel to the longitudinal axis of the bridge, Mc:

Vertical reinforcement bar size =		#	5
Vertical reinforcement bar spacing =		9	inches
Average parapet thickness =	min. width at base	15.00	inches
Total Area of Steel =	override	0.41	inches^2/foot
'd' = thickness of design section - cover - bar size/16 =	12.00	12.00	inches
Resistance Factor, phi (AASHTO 5.5.4.2) =		0.75	

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Section Capacity, Mn = T(d-a/2)	override		
C = T = as*fy =	6.79	6.79	kips/foot
h = 'd' =	based on #5 anchors only	12.00	inches
B1 = 0.85-0.05(f'c - 4000)/1000 <0.85 =		0.85	
a = C/bB1f'c =		0.19	inches
Mc = Mr = (phi)Mn =		5.05	foot-kips/foot

Flexural resistance of cantilevered parapet about vertical axis, Mw:

Horizontal reinforcement bar size =	#	4
Number of bars at front or back face =	4	bars
Average parapet thickness =	15.0	inches
Total Area of Steel =	0.79	inches^2/foot
'd' = thickness of design section - cover - bar size/16 =	12.13	inches
phi (AASHTO 1.3.2 for extreme event limit state) =	1.0	

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Section Capacity, Mn = T(d-a/2)		
C = T = as*fy =	47.12	kips/foot
h = 'd' =	12.13	inches
B1 = 0.85-0.05(f'c - 4000)/1000 <0.85 =	0.85	
a = C/bB1f'c =	1.32	inches
Mw = Mr = (phi)Mn =	45.02	foot-kips/foot

Nominal resistance to transverse load, Rw:	Note, calcs are for impacts w/in segment, not at ends		
Additional flexural resistance at top of wall, Mb =		0.0	foot-kips
Longitudinal Length of distribution of impact force, Lt (LRFD T. A13.2.1) =		3.5	feet
Height of Parapet, H =		2.67	feet
Critical length of yield line, Lc (LRFD A13.3.1-2) =		15.65	feet
Resistance, Rw (LRFD A13.3.1-1) =		59.30	kips
Transverse Load, Ft (LRFD T.A13.2.1) =		54.0	kips

Status = *Sufficient Capacity is Provided*