U.S. Department of Transportation
Federal Highway Administration

1200 New Jersey Avenue, SE
Washington, D.C. 20590

September 14, 2009

In Reply Refer To:
HSSD/B-170B

Mr. Donald S. Turner
Traffic Safety and Design Engineer
South Carolina Department of Transportation
P.O. Box 191
Columbia, SC 29202-0191

Dear Mr. Turner:

This letter is in response to your most recent request for the Federal Highway Administration (FHWA) acceptance of a roadside safety system for use on the National Highway System (NHS). Related to this request is the existing FHWA Acceptance Letter B-170A requesting the South Carolina's DOT (SCDOT) immediate attention regarding issues that rendered Acceptance Letter B-170 inadequate. Since your current submission has addressed these issues, your request is that we find the following system acceptable for use on the NHS under the provisions of National Cooperative Highway Research Program (NCHRP) Report 350 "Recommended Procedures for the Safety Performance Evaluation of Highway Features."

Name of system: South Carolina DOT (SCDOT) Temporary Concrete Barrier
Type of system: Temporary Concrete Barrier Wall and Anchorage
Test Level: NCHRP Report 350 Test Level 3 (TL-3)
Testing conducted by: Acceptance via Equivalence and Computational Analysis conducted by South Carolina Department of Transportation
System Designator: SWC13
Date of request: July 27, 2009

Requirements
Roadside safety systems should meet the guidelines contained in the NCHRP Report 350, "Recommended Procedures for the Safety Performance Evaluation of Highway Features". FHWA Memorandum "ACTION: Identifying Acceptable Highway Safety Features" of July 25, 1997, provides further guidance on crash testing requirements of longitudinal barriers.

Description

The SCDOT concrete bridge barrier (barrier) is a temporary barrier system that incorporates temporary anchorage. The barrier is 32 inches high, 6 inches wide at the top, and 24 inches wide at the base. The barrier is a New Jersey profile concrete barrier that was successfully crash tested per NCHRP Report 350 and accepted on NHS highways as per Acceptance Letter B-98 as a free standing barrier. The current request for anchored barrier required revised reinforcement as per the attached design computation and specifications. In addition the specified anchor system(s) for this temporary barrier are as follows:

A. As specified in FHWA B-5, except generic and non-proprietary materials shall be specified. The anchors will be 16 inch long and 1 inch diameter A449 fully threaded galvanized rods. Each 10 foot section of temporary concrete barrier will be anchored on the traffic side with five (5) anchors. The anchor rods will pass through a slot fabricated into the barrier wall and inserted into a 1 1/8-inch diameter hole 6-1/2 inches deep into the concrete bridge deck. Each anchor will be secured in the anchor hole with a two-component epoxy-resin bonding agent. Drawings illustrating the temporary concrete barrier with the anchorage system are as per FHWA B-5, as are the epoxy grouting specifications.
B. As specified through-bolt anchor system design computation as attached to this correspondence that utilizes variable length 1-inch diameter A449 fully threaded galvanized bolts for anchors. Each 10-foot section of barrier wall will be anchored on the traffic side with five (5) anchors. The anchor bolt will pass from underneath the bridge deck through a barrier washer, the bridge deck via a typical 1 1/8-inch diameter hole drilled through the bridge deck, a slot fabricated into the barrier wall, a second barrier washer, and a heavy hex nut. To secure each anchor, tighten the nut of the anchor system snug and peen the threads of the anchor bolt to prevent back turning of the nut. Repeat this procedure for each anchor.

Findings

We concur that based upon equivalence and computation the SCDOT Temporary Concrete Barrier meets all barrier structural adequacy and vehicle trajectory criteria as outlined in NCHRP Report 350 and is acceptable for use on the NHS as a TL-3 barrier when allowed by the highway agency. Please note the following standard provisions that apply to FHWA letters of acceptance:

- This acceptance is limited to the crashworthiness characteristics of the system and does not cover their structural features, nor conformity with the Manual on Uniform Traffic Control Devices.
- Any changes that may adversely influence the crashworthiness of the system will require a new acceptance letter.
- Should the FHWA discover that the qualification testing was flawed, that in-service performance reveals unacceptable safety problems, or that the system being marketed is significantly different from the version that was crash tested, we reserve the right to modify or revoke our acceptance.
- You will be expected to supply potential users with sufficient information on design and installation requirements to ensure proper performance.

- You will be expected to certify to potential users that the hardware furnished has essentially the same chemistry, mechanical properties, and geometry as that submitted for acceptance, and that it will meet the crashworthiness requirements of the FHWA and the NCHRP Report 350.
- To prevent misunderstanding by others, this letter of acceptance is designated as number B-170B and shall not be reproduced except in full. This letter and attached computational documentation upon which it is based are public information. All such letters and documentation may be reviewed at our office upon request.
- This acceptance letter shall not be construed as authorization or consent by the FHWA to use, manufacture, or sell any patented system for which the applicant is not the patent holder. The acceptance letter is limited to the crashworthiness characteristics of the candidate system, and the FHWA is neither prepared nor required to become involved in issues concerning patent law. Patent issues, if any, are to be resolved by the applicant.

Sincerely yours,

David A. Nicol, P.E.
Director, Office of Safety Design
Office of Safety

Enclosures

DESIGN OF SCDOT TEMPORARY CONCRETE BARRIER

Designed By : Steve Nanney
Checked By : Barry Bowers
Date : 7/27/2009

Design Criteria:

AASHTO 2007 LRFD Bridge Design Specifications, 4th. Edition, with 2008 Interim Revisions.

TL-3 - Test Level Three

SCDOT Bridge Design Memorandum DM0408

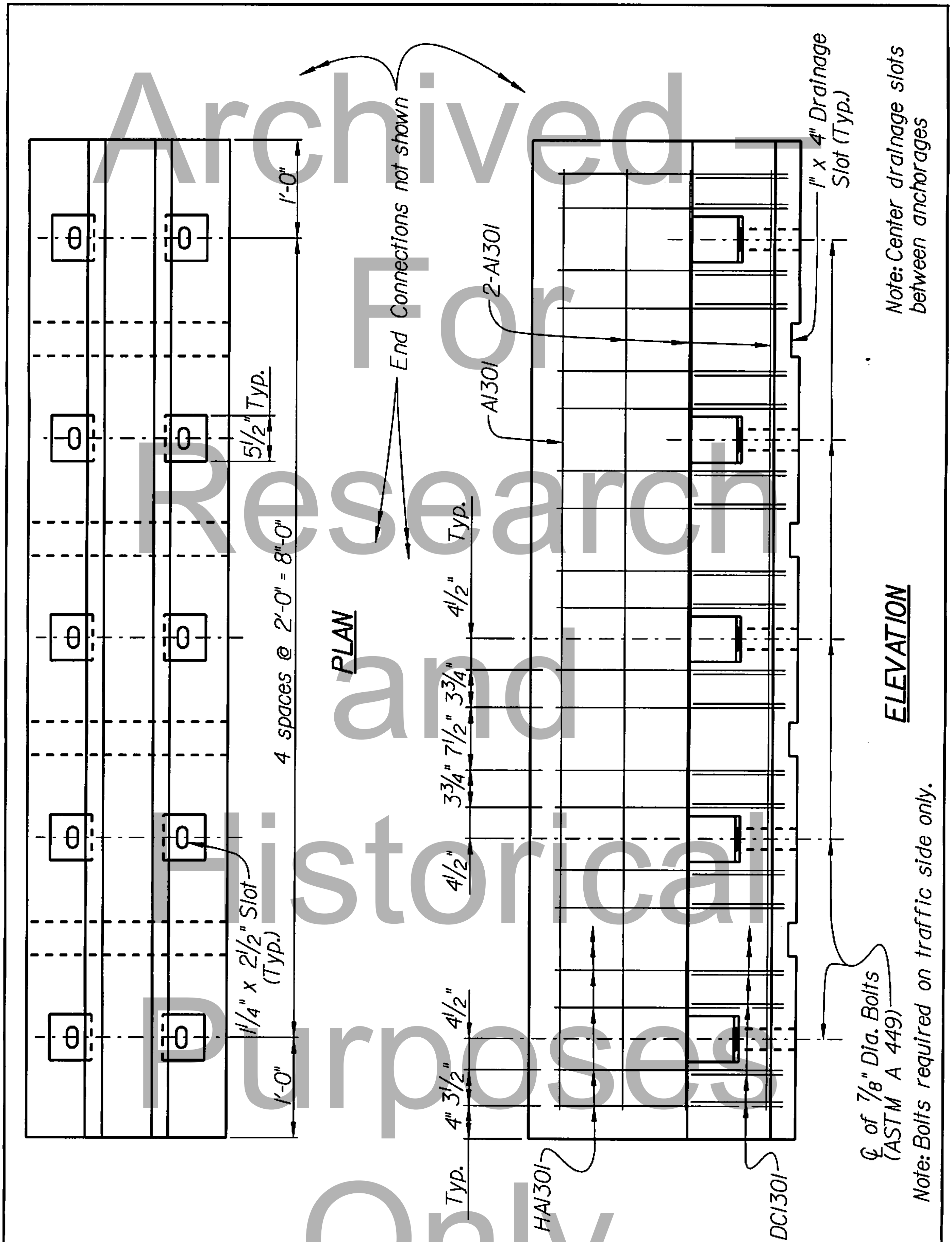
f'c = 3 ksi
fy = 60 ksi
Concrete Cover = 1.5 in

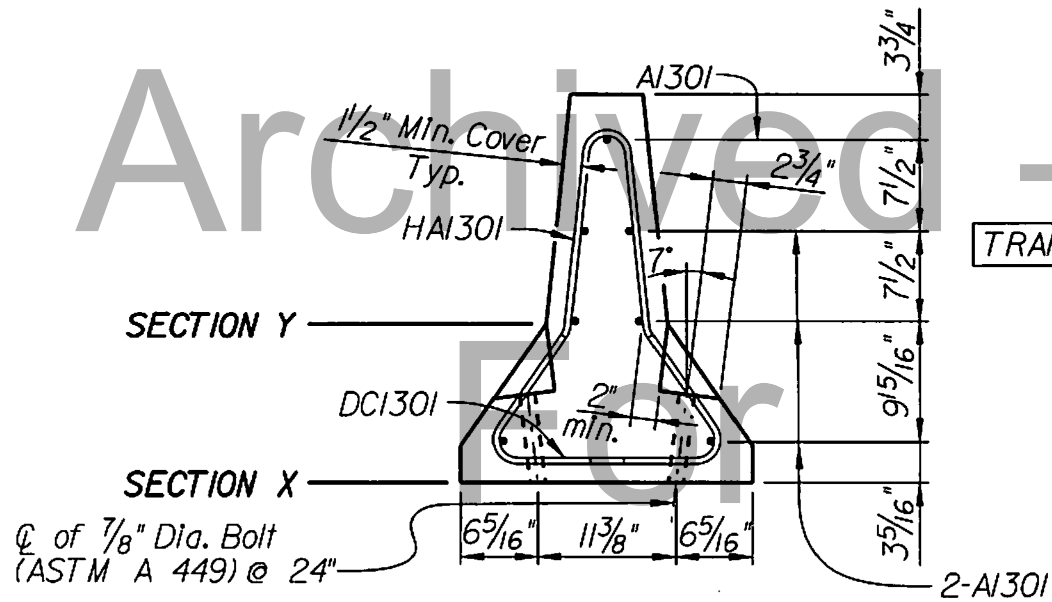
Φ = 1.0 (Extreme Event Loading)

ASTM A 449 Anchor Bolts used for Anchorage (fy = 92 ksi)

Specified Minimum Bond Strength of Adhesive = 1.5 ksi

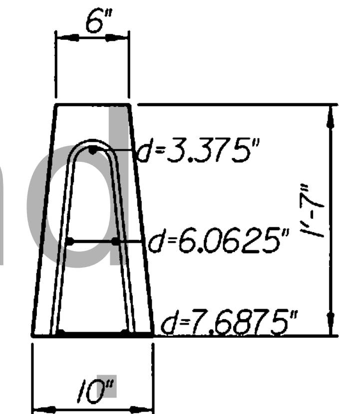
Minimum Barrier Segment Length is 10 feet


End Connections not shown
PLAN
1'-0"
4 spaces @ 2'-0" = 8'-0"
1'-0"
5 1/2" Typ.
1 1/4" x 2 1/2" Slot (Typ.)
2-A1301
A1301
HA1301
DC1301
4 1/2" Typ.
3 3/4" 7 1/2" 3 3/4"
4 1/2"
4" 3 1/2" 4 1/2" Typ.
1" x 4" Drainage Slot (Typ.)
Note: Center drainage slots between anchorages
ELEVATION
℄ of 7/8" Dia. Bolts (ASTM A 449)
Note: Bolts required on traffic side only.

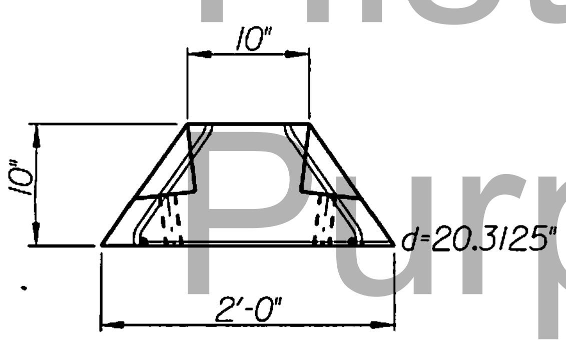


SECTION THRU BARRIER

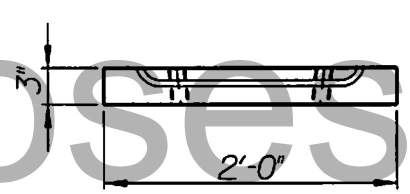
Note:
Anchorage required only on traffic side of barrier when barrier is within 5 feet of edge of deck.



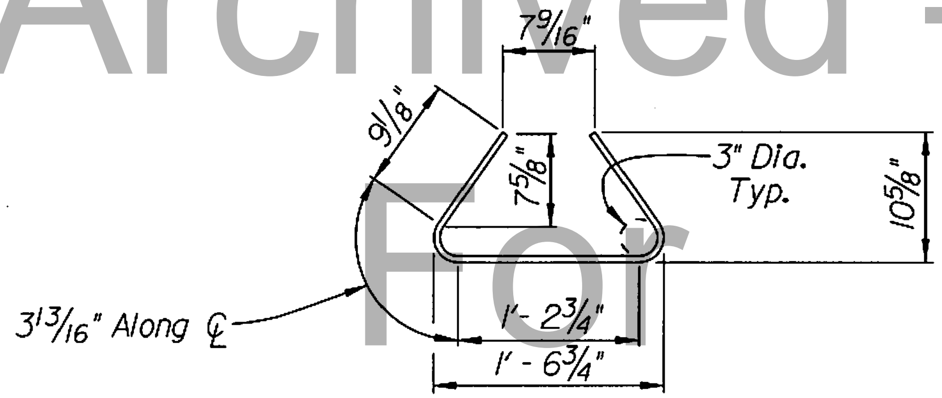
SEGMENT A



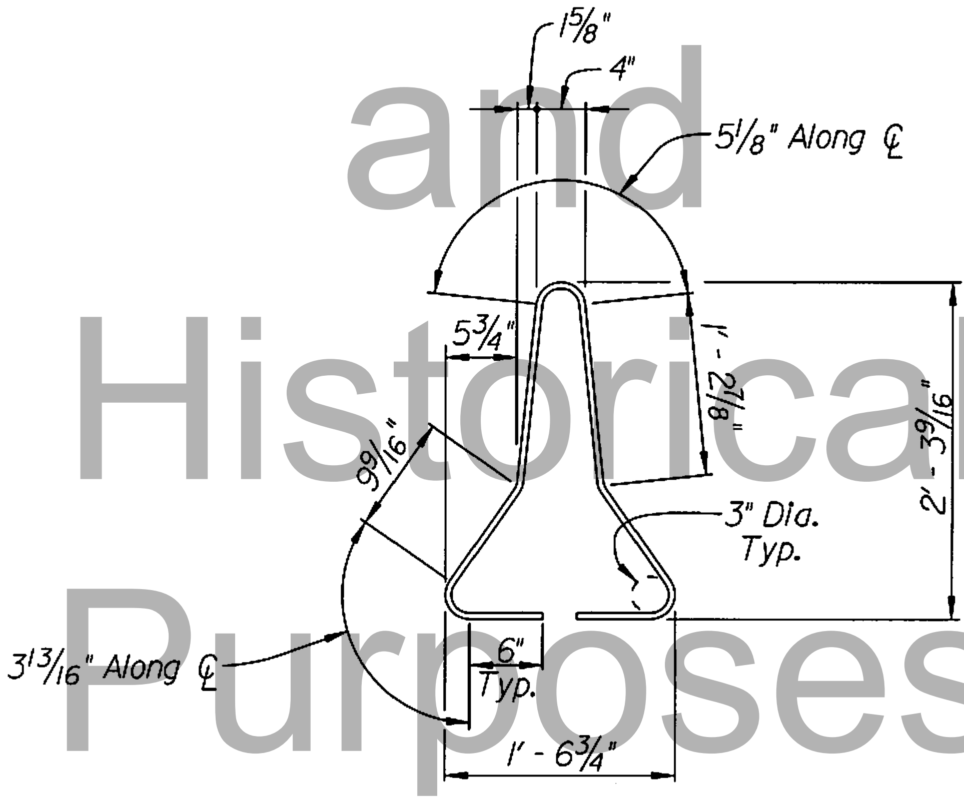
SEGMENT B



SEGMENT C


7 9/16"
9 1/8"
7 5/8"
3" Dia.
Typ.
10 5/8"
3 13/16" Along ℄
1'- 2 3/4"
1' - 6 3/4"

DC Bar


1 5/8"
4"
5 1/8" Along ℄
5 3/4"
1'- 2 1/8"
2'- 3 9/16"
9 9/16"
3" Dia.
Typ.
3 13/16" Along ℄
6"
Typ.
1' - 6 3/4"

HA Bar

Designed By : SAN
Checked By : BWB
Date : 7/27/2009

Barrier Design

Moment Capacity about Longitudinal Axis, Mc (ft-kips/ft)

	Segment A	Segment B	Segment C
fy (ksi)	60	60	60
f'c (ksi)	3	3	3
As (in2)	0.4	0.4	0.4
segment ht. (in)	19	10	3
b (in)	12	12	12
d (in)	6.24	14.864	20.21785
a (in)	0.7843	0.7843	0.7843
Mc (ft-kips/ft)	11.70	28.94	39.65

Ave. Mc (ft-kips/ft) for Section X = 19.71

Mc (ft-kips/ft) for Section Y = 11.70

Moment Capacity about Vertical Axis, Mw (ft-kips)

	Segment A	Segment B	Segment C
fy (ksi)	60	60	60
f'c (ksi)	3	3	3
As (in2)	0.6	0.2	0
ave. thickness (in)	8	17	24
b (in)	19	10	3
d (in)	5.7083	13.3125	0
a (in)	0.7430	0.4706	0.0000
Mw (ft-kips)	16.01	13.08	0.00

Mw (ft-kips) for Section X = 29.09

Mw (ft-kips) for Section Y = 16.01

Designed By : SAN
Checked By : BWB
Date : 7/27/2009

For Collisions near Joint

Lc (ft) = Lt/2 + SQRT((Lt/2)*(Lt/2) + H*(Mb + Mw)/Mc)
Rw (kips) = (2/(2*Lc - Lt))*(Mb + Mw + Mc*Lc*Lc/H)

Section X		Section Y	
Lt (ft) =	4	Lt (ft) =	4
H (ft) =	2.67	H (ft) =	1.58333
Mb (ft-kips) =	0	Mb (ft-kips) =	0
Mw (ft-kips) =	29.09	Mw (ft-kips) =	16.01
Mc (ft-kips/ft) =	19.71	Mc (ft-kips/ft) =	11.70
Lc (ft) =	4.82	Lc (ft) =	4.48
Rw (kips) =	71.12	Rw (kips) =	66.24

Rw > 54 kips OK

Designed By : SAN
Checked By : BWB
Date : 7/27/2009

Barrier Anchorage

Moment

For 54 kips spread over 4 ft plus 2.67 ft (Lt + H)

Required Moment Capacity (ft-kips/ft) = 54*2.67/(4 + 2.67)
= 21.6 ft-kips/ft

For 0.875" diameter ASTM A 449 Bolts at 24" o.c. (fy = 92 ksi)

Resisting Moment = Φ*As*fy*(d-a/2)/12

a = As*fy/(0.85*f'c*b)
= 0.3*92/(0.85*3*12)
= 0.90 in

Resisting Moment = 1.0*0.3*92*(17.6875-0.90/2)/12
= 39.65 ft-kips/ft

39.65*cos(7) = 39.35 39.35 ft-kips/ft > 21.6 ft-kips/ft OK

Determine Tensile Force in Anchor Bolt caused by 54 kip Load

For a = 0.5

21.6 = 1.0*0.3*f*(17.6875-0.5/2)/12
f = 49.5 ksi a = 0.3*49.5/(0.85*3*12) = 0.485

Try a = 0.485

21.6 = 1.0*0.3*f*(17.6875-0.485/2)/12
f = 49.5 ksi OK

Tension in bolt = 49.5*(0.6)/cos(7) = 29.9 kips

From SCDOT Guidelines for Design of Adhesively Bonded Anchors:

ΦNs = Φ*Ae*fy
= 1.0*(0.6)*(92)
= 55.2 kips 55.2 kips > 29.9 kips OK

ΦNp = Φ*T*π*dia*he (For 12" embedment)
= 1.0*(1.5)*(3.14)*(0.875)*(12)
= 49.5 kips 49.5 kips > 29.9 kips OK

Designed By : SAN
Checked By : BWB
Date : 7/27/2009

Shear

For 54 kips spread over 4 ft plus 2.67 ft (Lt + H)

Required Shear Capacity (ft-kips/ft) = 54/(4 + 2.67)
= 8.1 kips/ft

Assuming a friction factor of 0.4 and neglecting the weight of the barrier:

Shear resisted by friction = 29.9*cos(7)*(0.4)/2 = 5.9 kips/ft
(From compressive force on concrete due to overturning moment)

From SCDOT Guidelines for Design of Adhesively Bonded Anchors:

Shear resisted by each bolt = ΦVs = Φ*(0.7)*Ae*fy
= 1.0(0.7)*(0.6)*(92)
= 38.6 kips

Total Shear Resistance per foot:

ΦVn = 5.9 + 38.6/2
= 25.2 kips/ft

25.2 kips/ft > 8.1 kips/ft OK

Interaction of Moment and Shear

From SCDOT Guidelines for Design of Adhesively Bonded Anchors:

Nu/(ΦNn) + Vu/(ΦVn) ≤ 1.0
29.9/49.5 + 8.1/25.2 = 0.93 OK

Embedment

Determine minimum embedment to ensure ductile shear failure:

he = 0.7*(1.25)*As*fy/(T*π*dia)
= 0.7*(1.25)*(0.6)(92)/(1.5*π*(0.875))
= 11.7 in

Use 12 inch embedment depth for adhesive anchor bolts
(For slabs < 14" thick, use bolt through anchorages)

Field Test Load

From SCDOT Guidelines for Design of Adhesively Bonded Anchors:

Test Load = 0.85*T*Π*dia*he
= 0.85*(1.5)*(3.14)*(0.875)*(12)
= 42 kips

Field Test Load = 42 kips

Project: Temporary Barrier LRFD Design
Design: SAN   Check: BWB
Date: 7/27/09

Reference: *Design of Highway Bridges*
Barker & Puckett, 1997, Ch. 7.10.M

Capacity of Horizontal Reinf. Mw (Moment Capacity about Vertical Axis)

Φ =	1.00		**Vert Reinf**	
f'c =	3 ksi		Bar Size =	4
fy rebar =	60 ksi		Spacing =	6 in
fy anchor bolt =	92 ksi		As vert =	0.4 in^2/ft
			Clear Cover =	1.5 in

Section 1 (Top of Barrier): (Segment A)

		Horiz Reinf	
Wtop1 =	6 in	Bar Size =	4
Wbot1 =	10 in	# of bars =	3
Ht1 =	19 in	As horiz =	0.6 in^2/section

Vert location of Horiz Reinf	Dist from top of Section 1	Barrier Width at bar location		d
Bar 1 =	3.75 in	6.750 in		3.375 in
Bar 2 =	11.25 in	8.313 in		6.063 in
Bar 3 =	18.75 in	9.938 in		7.688 in
			d avg =	5.708 in

a = (As*fy rebar)/(0.85*f'c*Ht1)
a = 0.743 in

ΦMw1 = Φ *As*(fy rebar)* (d - a/2)/12
ΦMw1 = 16.01 ft*kip

Section 2 (Middle of Barrier): (Segment B)

		Horiz Reinf	
Wtop2 =	10 in	Bar Size =	4
Wbot2 =	24 in	# of bars =	1
Ht2 =	10 in	As horiz =	0.2 in^2/section

Vert location of Horiz Reinf	Dist from top of Section 2	Barrier Width at bar location		d
Bar 1 =	9.6875 in	23.563 in		20.313 in
		10.000 in		6.313 in
			d avg =	13.31 in

a = (As*fy rebar)/(0.85*f'c*Ht2)
a = 0.471 in

ΦMw2 = Φ *As*(fy rebar)* (d - a/2)/12
ΦMw2 = 13.08 ft*kip

Section 3 (Bottom of Barrier): (Segment C)

		Horiz Reinf	
Wtop3 =	24 in	Bar Size =	4
Wbot3 =	24 in	# of bars =	0
Ht3 =	3 in	As horiz =	0 in^2/section

Project: Temporary Barrier LRFD Design
Design: SAN **Check: BWB**
Date: 7/27/09

Capacity of Horizontal Reinforcing (Con't):

Vert location of Horiz Reinf	Dist from top of Section 3	Barrier Width at bar location	d
Bar 1 =	0 in	24.000 in	0.000 in

a = (As*fy rebar)/(0.85*f'c*Ht2)
a = 0.000 in

ΦMw3 = Φ *As*(fy rebar)* (d - a/2)/12
ΦMw3 = 0.00 ft*kip

Total Capacity of Horizontal Reinf. in Barrier: (Section X)

ΦMw Total = ΦMw1 + ΦMw2 + ΦMw3 = 29.09 ft*kip

Capacity of Horizontal Reinf. in Barrier 13" above Base: (Section Y)

ΦMw Total = ΦMw1 = 16.01 ft*kip

Project: Temporary Barrier LRFD Design
Design: SAN   **Check:** BWB
Date: 7/27/09

Capacity of Vertical Reinf. Mc (Moment Capacity about Horizonal Axis)

		Vert Reinf	
Φ =	1.00	Bar Size =	4
f'c =	3 ksi	Spacing =	6 in
fy rebar =	60 ksi	As vert =	0.4 in^2/ft
fy anchor bolt =	92 ksi	Clear Cover =	1.5 in

Section 1 (Top of Barrier):

Wtop1 =	6 in	d avg =	6.25 in
Wbot1 =	10 in		
b =	12 in		

a = (As*fy rebar)/(0.85*f'c*b)
a = 0.784 in

ΦMc1 = Φ *As*(fy rebar)* (d - a/2)/12
ΦMc1 = 11.72 ft*kip/ft

Section 2 (Middle of Barrier):

Wtop2 =	10 in	d top =	8.25 in
Wbot2 =	24 in	d bot =	21.588 in
b =	12 in	d avg =	14.919 in

a = (As*fy rebar)/(0.85*f'c*b)
a = 0.784 in

ΦMc2 = Φ *As*(fy rebar)* (d - a/2)/12
ΦMc2 = 29.05 ft*kip/ft

Section 3 (Bottom of Barrier):

Wtop3 =	24 in	d avg =	20.375 in
Wbot3 =	24 in		
b =	12 in		

a = (As*fy rebar)/(0.85*f'c*b)
a = 0.784 in

ΦMc3 = Φ *As*(fy rebar)* (d - a/2)/12
ΦMc3 = 39.97 ft*kip/ft

Total Capacity of Vertical Reinf. in Barrier: (Section X)

ΦMc Total = [(ΦMc1*Ht1) + (ΦMc2*Ht2) + (ΦMc3*Ht3)]/(Ht1 + Ht2 + Ht3)
ΦMc Total = 19.78 ft*kip/ft

Capacity of Vertical Reinf. in Barrier 13" above Base: (Section Y)

ΦMc Section B = 11.72 ft*kip/ft

Project: **Temporary Barrier LRFD Design**
Design: **SAN** Check: **BWB**
Date: **7/27/09**

Calculate LC & RW

Lt = 4.0 ft for TL- 3

At Base of Barrier H = 2.6667 in Section X

For Impact at end of wall/joint:

Lc = $Lt/2 + [(Lt/2)^2 + H*(Mb + Mw)/Mc]^{0.5}$

Lc = 4.81 ft

Mb = 0 ft*kip
Mw = 29.09 ft*kip
Mc = 19.78 ft*kip/ft

Rw = $(2/(2*Lc - Lt))*(Mb + Mw + Mc*Lc^2/H)$

Rw = 71.43 kip **OK**

For Impact in wall segment:

Lc = $Lt/2 + [(Lt/2)^2 + 8*H*(Mb + Mw)/Mc]^{0.5}$

Lc = 7.95 ft

Rw = $(2/(2*Lc - Lt))*(8*Mb + 8*Mw + Mc*Lc^2/H)$

Rw = 117.91 kip **OK**

13" Above Base of Barrier H = 1.5833 in Section Y

For Impact at end of wall/joint:

Lc = $Lt/2 + [(Lt/2)^2 + H*(Mb + Mw)/Mc]^{0.5}$

Lc = 4.48 ft

Mb = 0 ft*kip
Mw = 16.01 ft*kip
Mc = 11.72 ft*kip/ft

Rw = $(2/(2*Lc - Lt))*(Mb + Mw + Mc*Lc^2/H)$

Rw = 66.34 kip **OK**

For Impact in wall segment:

Lc = $Lt/2 + [(Lt/2)^2 + 8*H*(Mb + Mw)/Mc]^{0.5}$

Lc = 6.62 ft

Rw = $(2/(2*Lc - Lt))*(8*Mb + 8*Mw + Mc*Lc^2/H)$

Rw = 97.91 kip **OK**

Project: Temporary Barrier LRFD Design
Design: SAN **Check: BWB**
Date: 7/27/09

Moment Capacity of Anchorage

Anchor Bolt Checks: AASHTO LRFD/SCDOT Supplemental Spec. for Adhesively Anchored Dowels

Fu anchor bolt =	120 ksi	Bolt diam. =	0.875 in
fy anchor bolt =	92 ksi	Anominal bolt =	0.601 in^2/bolt
f'c =	3 ksi	Bolt spacing =	24 in
Φ =	1.00	As prov =	0.301 in^2/ft
		Angle =	7 degrees

Moment capacity of anchor bolt: distribution length = height + Lt

Force = 54 kips TL- 3 — d = 17.688 in
Moment arm, H = 2.6667 ft — b = 12 in
Moment = 144.00 ft*kip
Distribution Length = 6.6667 ft (Lt + H) — Req'd Capacity = 21.60 ft*kip/ft

a = (As prov*fy anchor bolt)/(0.85*f'c*b) = 0.904 in — Eq 2

Bolt M Capacity = Φ *As prov*(fy anchor bolt)* (d - a/2)/12 = 39.7 ft*kip/ft — Eq 1 — **OK**

Bolt stress at 54 kip impact load: ΦMn req'd = 21.60 ft*kip/ft

Check w/ a = 0.904	Solve Eq 1 for actual stress in bolt at 54k load ==>	f_{actual} =	50.019 ksi
		a =	0.491 in
Iterate w/ a = 0.491	Solve Eq 1 for actual stress in bolt at 54k load ==>	f_{actual} =	49.43 ksi
		a =	0.486 in
Iterate w/ a = 0.486	Solve Eq 1 for actual stress in bolt at 54k load ==>	f_{actual} =	49.42 ksi
		a =	0.486 in

Vertical Component of Force in Bolt = 29.72 kips
Tensile Force in Bolt = (Tensile Force in Bolt)/Cos(Angle) = **29.94 kips**

Tensile capacity of anchor bolt: SCDOT Adhesively Bonded Anchor & Dowel Guidelines

$\Phi Nn = \min$ of:
Φ*Ns = Φ*(Anominal bolt*fy anchor bolt) = 55.32 kip/bolt
Φ*Np = Φ*ψe*ψs*Nc = 49.48 kip/bolt <=== Governs

Anchor Bond Capacity: Tension Base on 12" embedment

he = 12 in
T = 1.5 ksi
Nc = T*π*Bolt diam.*he — ψ_e = 1
Nc = 49.48 kips — ψ_s = 1

Min. tensile capacity of anchor bolt = 49.48 kips
Tensile force in anchor bolt = 29.94 kips — **OK**

Project: Temporary Barrier LRFD Design
PCN: SAN **Check: BWB**
Date: 7/27/09

Shear Capacity of Anchorage

Shear capacity of anchor bolt: distribution length = height + Lt

Force = 54 kips TL- 3
Distribution Length = 6.6667 ft (Lt + H) Req'd Capacity = 8.1 kip/ft

Shear Friction at interface: Assume friction factor = 0.4, ignore barrier self weight
Consider clamping force caused by overturning moment due to impact

Barrier Width = 24 in Acv = 288 in^2 c = 0 ksi
Unit Length = 12 in μ = 0.4

P = Clamping force/Bolt spacing = 14.86 kips/ft (Vertical Component only)

ΦVf = c*Acv + μ*P = 5.94 kips/ft

Shear capacity of anchor bolt:

ΦVs = Horiz. Component = Φ *(0.7*Anom. bolt*Fy anchor bolt*# shear planes = 38.73 kip/bolt

Total Shear Capacity per anchor bolt (interface + anchor bolt):

ΦVn = ΦVf + ΦVs/2 = 25.31 kip/ft **OK**

Combined Tension and Shear: SCDOT Adhesively Bonded Anchor & Dowel Guidelines

(Nu/ΦNn) + (Vu/ΦVn) =< 1.0 = **0.921** **OK**

Nu = 29.72 kips
ΦNn = 49.48 kips
Vu = 8.10 kips
ΦVn = 25.31 kips

Anchor Bond Capacity: Shear

he req'd = 0.7*(1.25*Anominal bolt*Fy anchor bolt)/(T*π*bolt diameter)
he req'd = 11.74 in ==> **Use 12 in**

Field Test Load: (SCDOT Adhesively Bonded Anchor & Dowel Guidelines)

Test Load = min | 0.85*Nc = 42.06 kips <=== Governs
| 0.9*Ae*fy anchor bolt= 49.79 kips

Req'd Test Load = 42 kips