South Carolina
Department of Transportation

BRIDGE DESIGN MEMORANDUM – DM0408

TO: RPG Structural Engineers
Structural Design Consultants

DATE: June 16, 2008

RE: Adhesively Bonded Anchors and Dowels

Beginning with the September 2008 Letting, the Supplemental Specification for Adhesively Bonded Anchors and Dowels should be included in all Department Contracts where adhesive anchorages are specified or permitted. This specification contains requirements for the installation and testing of adhesive anchorages and is available at the Department's website.

The attached "Guidelines for Design of Adhesively Bonded Anchors and Dowels" should be followed when designing adhesive anchorages. The designer shall specify on the plans if field testing is required and, if field testing is required, the designer shall also specify the test load. For each adhesive anchor application that is specified or permitted, one of the following notes shall be included on the plans:

- For applications where field testing is required
  Provide and install anchorages in accordance with the requirements of the Supplemental Specification for Adhesively Bonded Anchors and Dowels. Use an adhesive bonding system that has a minimum bond strength of 1.5 ksi. Field test the anchorages, using a test load of ____ kips per anchor, in accordance with the requirements of the Supplemental Specification.
- For applications where field testing is not required
  Provide and install anchorages in accordance with the requirements of the Supplemental Specification for Adhesively Bonded Anchors and Dowels. Use an adhesive bonding system that has a minimum bond strength of 1.5 ksi. Field testing of the anchorages is not required.

See Section 3.0 of the attached Guidelines for applications where field testing should be required and for the method to determine the magnitude of the test load.

E. S. Eargle
Preconstruction Support Engineer

ESE:bwb
Attachment
cc: Bridge Construction Engineer
Bridge Maintenance Engineer
Director of Traffic Engineering
FHWA Structural Engineer
Materials and Research Engineer
Preconstruction Support Managers
Regional Production Engineers
RPG Design Managers
File: PC/BWB

GUIDELINES FOR
DESIGN OF ADHESIVELY BONDED ANCHORS AND DOWELS

1.0 Notation

A_e = effective cross sectional area of steel anchor (in^2)
A_{no} = effective area of a single anchorage in tension (in^2) See Figure 1.1.
A_n = effective area of a group of anchorages in tension (in^2) See Figure 1.1.
A_{vo} = effective area of a single anchorage in shear (in^2) See Figure 1.2.
A_v = effective area of a group of anchorages in shear (in^2) See Figure 1.2.
c = anchorage edge distance, measured from free edge to centerline of anchorage (in)
d = diameter of steel anchor (in)
f'_c = specified minimum 28-day compressive strength of concrete (ksi)
f_y = specified minimum yield strength of steel anchor (ksi)
h = concrete member thickness (in)
h_e = embedment depth of steel anchor (in)
N_c = nominal tensile resistance of anchorage as controlled by concrete embedment (kips)
N_n = nominal tensile resistance of anchorage (kips)
N_p = nominal tensile resistance of anchorage as controlled by pullout (kips)
N_s = nominal tensile resistance of anchorage as controlled by anchor steel strength (kips)
N_u = factored tensile load (kips)
s = anchorage spacing (in)
V_c = nominal shear resistance of anchorage as controlled by concrete embedment (kips)
V_n = nominal shear resistance of anchorage (kips)
V_s = nominal shear resistance of anchorage as controlled by anchor steel strength (kips)
V_u = factored shear load (kips)
T = specified minimum bond strength of adhesive (ksi)
ϕ_c = 0.85, resistance factor used for anchorage controlled by concrete embedment
ϕ_s = 0.90, resistance factor used for anchorage controlled by anchor steel strength
Ψ_e = modification factor for anchorage in tension having an edge distance less than 8d
Ψ_s = modification factor for a group of anchorages in tension having a spacing less than 16d
Ψ_v = modification factor for anchorages in shear

2.0 Design Requirements

2.1 General Requirements

a. Where practical, anchorage spacing, s, should be 16d or greater and anchorages should have an edge distance, c, greater than or equal to 8d. Anchorage spacing, s, shall not be less than 12d and anchorages shall have an edge distance, c, greater than or equal to 5d.

b. The minimum concrete member thickness, h, shall be greater than or equal to $2d + h_e$.

c. Adhesive anchorages should be designed for a ductile failure. A ductile failure may be assumed when the following embedment depths are used:
   - For Anchorages in Tension: An embedment depth, h_e, capable of achieving 125% of the specified minimum yield strength of the anchor, f_y
   - For Anchorages in Shear: An embedment depth, h_e, equal to 70% of the embedment depth required to achieve 125% of the specified minimum yield strength of the anchor, f_y

d. Adhesive anchorages shall not be used in overhead or upwardly inclined installations. See Figure 1.3.

e. Adhesive anchorages shall not be used in applications having predominately sustained tensile loads and lack of structural redundancy. Predominately sustained tensile loads are defined as loadings where the permanent component of the factored tensile load, N_u, exceeds 30% of the nominal tensile resistance, N_n.

f. Adhesive anchorages should not be used on prestressed concrete members.

2.2 Tensile Loading

Anchors loaded in tension shall have an embedment depth, h_e, greater than or equal to 8d.

Anchorages shall be designed such that:

$$\phi N_n \geq N_u$$

where:

$$\phi N_n = \text{the lesser of } \phi N_s \text{ or } \phi N_p$$

The tensile resistance of the anchorage steel shall be taken as:

$$\phi N_s = \phi_s A_e f_y$$

The tensile resistance of the anchorage bond shall be taken as:

$$\phi N_p = \phi_c \Psi_e \Psi_s N_c$$

where:

$\Psi_e = 1.0$ when $c \geq 8d$

and

$\Psi_e = 0.70 + 0.30 (c / 8d)$ when $8d > c \geq 5d$

$\Psi_s = 1.0$ when $s \geq 16d$

and

$\Psi_s = A_n / A_{no}$ when $16d > s \geq 12d$

$$N_c = T \pi d h_e$$

2.3 Shear Loading

Anchors loaded in shear shall have an embedment depth, h_e, greater than or equal to 6d.

Anchorages shall be designed such that:

$$\phi V_n \geq V_u$$

where:

ϕV_n = the lesser of ϕV_s or ϕV_c

The shear resistance of the anchorage steel shall be taken as:

$$\phi V_s = \phi_s 0.7 A_e f_y$$

The shear resistance based on concrete strength shall be taken as:

$$\phi V_c = \phi_c \Psi_v 0.317 \sqrt{d} \sqrt{f'_c} c^{1.5}$$

where:

$\Psi_v = 1.0$ when $s \geq 3c$ and $h \geq 1.5c$

and

$\Psi_v = A_v / A_{vo}$ when $s < 3c$ and/or $h < 1.5c$

2.4 Interaction of Tensile and Shear Loadings

For combinations of tensile and shear loadings, anchorages shall be designed such that:

$$(N_u / \phi N_n) + (V_u / \phi V_n) \leq 1.0$$

where:

ϕN_n = the lesser of ϕN_s or ϕN_p

ϕV_n = the lesser of ϕV_s or ϕV_c

3.0 Field Testing Requirements

3.1 Field Testing Applications

Field testing of adhesively bonded anchors and dowels should be required for the following applications:

- Anchor bolts used to attach metal railing posts to top of concrete rails or parapets
- Dowels used to attach cast-in-place wingwalls/headwalls/curtain walls to precast culverts
- Dowels used for bridge widening or staged construction between substructure units or bridge decks
- Anchor bolts for bearing replacements for rehabilitation work
- Attachments of guardrails to culverts
- Attachments of temporary concrete barrier to bridge decks

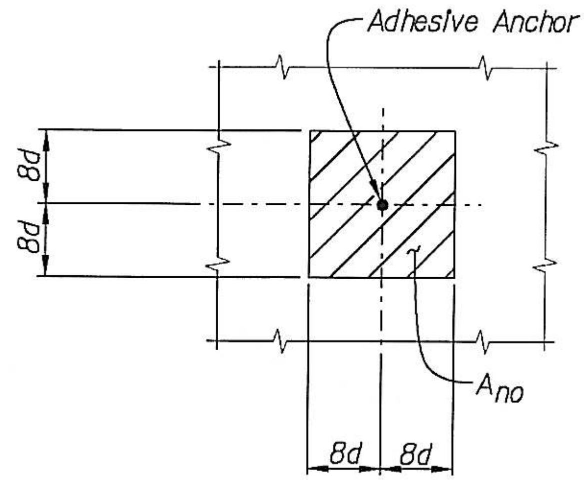
Field testing of adhesively bonded anchors and dowels should not be required for the following applications:

- Dowels used to attach sidewalks to bridge decks
- Dowels used for culvert extensions

For applications other than those listed above, the designer shall determine the need for field testing.

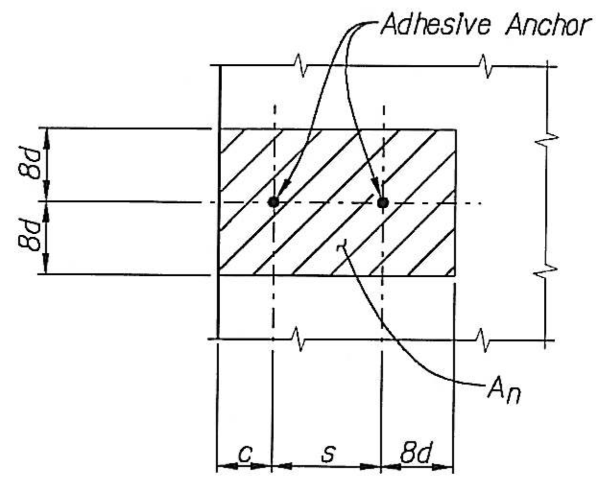
3.2 Field Test Loads

When field testing is required, the test load shall be specified on the Plans. The test load should be the lesser of 0.85 N_c or 0.9 A_e f_y.



PLAN

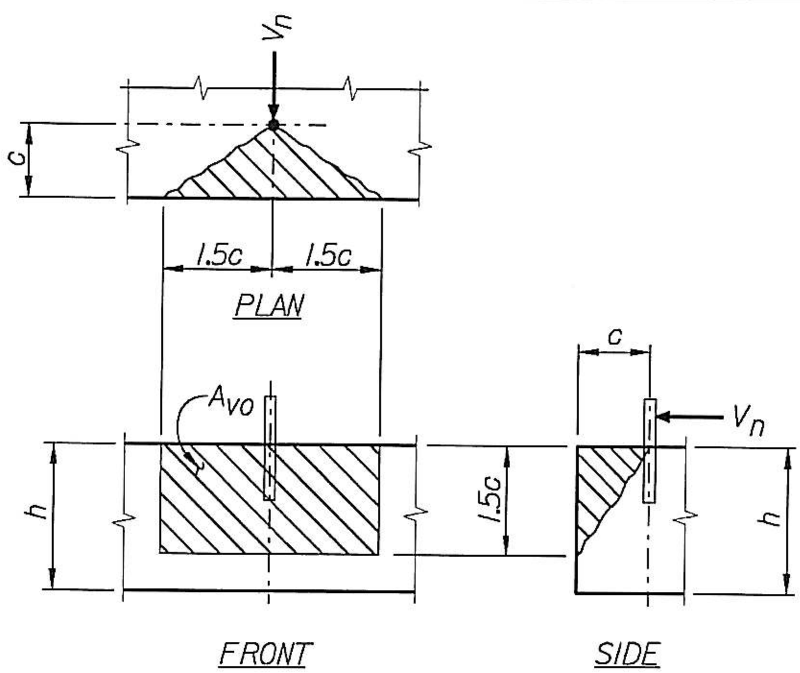
Showing Effective Tensile Area, A_{no}, When $c \geq 8d$ and $s \geq 16d$



PLAN

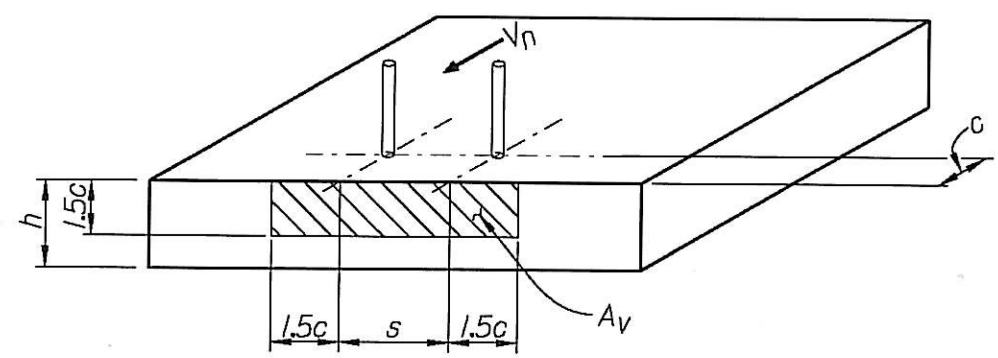
Showing Effective Tensile Area, A_n, When $5d \leq c < 8d$ and $12d \leq s < 16d$

FIGURE 1.1



DETAIL A

Showing Effective Shear Area, A_{VO}, When $s \geq 3c$



DETAIL B

Showing Effective Shear Area, A_V, When $s < 3c$

FIGURE 1.2

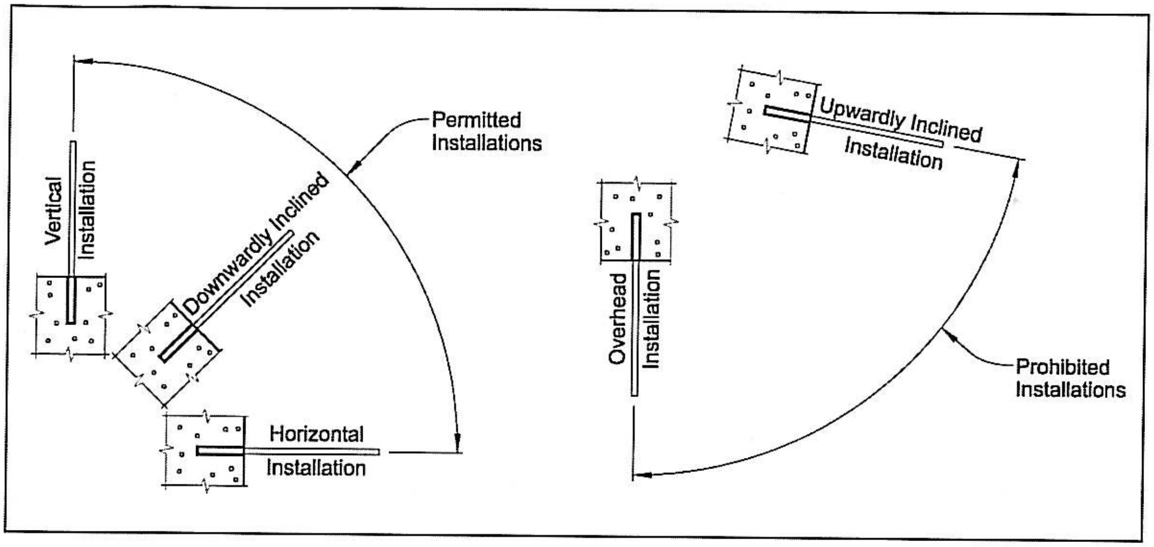

Permitted
Installations
Vertical
Installation
Downwardly Inclined
Installation
Horizontal
Installation
Upwardly Inclined
Installation
Overhead
Installation
Prohibited
Installations

FIGURE 1.3