5-81 ANCHORAGE TO CONCRETE

1. Introduction

Steel-to-concrete or concrete-to-concrete connections can be accomplished through the use of several types of anchorage systems. This design aid describes the concrete anchor systems that are most widely used on Caltrans' jobs and assists the designer in selecting the system that is best suited for a particular application.

2. Anchor Systems and Design Criteria

There are two broad types of anchor systems – post-installed anchors and cast-in-place (CIP) anchors.

The design recommendations for post-installed anchors in this aid conform to the requirements in the *California Amendments to AASHTO LRFD Bridge Design Specifications*.

For CIP anchors, the design recommendations are based on ACI 318-08 as well as *California Amendments to AASHTO LRFD Bridge Design Specifications*.

The designer should determine the loading combinations and the corresponding load factors for each application.

3. Post-Installed Anchors

This type of an anchor is installed in a hole that is drilled in hardened concrete. There are two main types of post-installed anchors – Mechanical Expansion Anchors (MEA) and Bonded Anchors.

3.1 Mechanical Expansion Anchors

MEAs are inserted in pre-drilled holes. These anchors expand and bear against the concrete surface and are placed using any of the following techniques:

a) Hammering the anchor (deformation controlled)
b) Tightening a nut (torque controlled)
c) Expanding into an undercut (expanding into a notched opening at the bottom of a hole).

MEAs are frequently used to anchor minor or temporary attachments such as signs, brackets, inspection ladders, safety railing, utility pipes and light fixtures to hardened concrete. MEAs have the following advantages:

- Are inexpensive
- Are quick and easy to install
- Can be installed in any orientation
- Loading can be applied immediately after installation

MEAs have the following disadvantages:

- Have relatively small tensile strength
- Are not recommended for use in tension zone where concrete is likely to crack
- Are not suitable for resisting dynamic (vehicle loading, seismic etc.) or vibratory loads

Materials and installation methods of MEAs must comply with the requirements of Section 75 of the *Standard Specifications*. Designers should refer to the Caltrans' "*Authorized Materials List*" for a list of approved MEAs.

Based on tests performed at the Transportation Laboratory (*Translab*) by the Office of Structure Materials, METS, the following two types of MEAs are currently approved for use on Caltrans' projects [John P. Dusel and Craig N. Harrington, 1986]:

a) Shell expansion anchor with internal threads –
This anchor requires an independent stud, nut and washer, and is stronger in tension than other types of shell anchors.

b) Integral stud anchor (wedge type and external plug) –
This anchor, which is furnished with nuts and washers, is easier to install in a multi-hole base plate and is stronger in shear.

Figure 3.1-1 shows some common types of MEAs.

With prior testing, other types of MEAs (example: undercut anchors) may be approved for use on Caltrans' jobs. While undercut anchors are relatively more expensive than shell and stud type anchors since additional drilling is required, they are better suited for dynamic loads.

Self-drilling MEAs, because of a potential for fatigue-related cracking in the hardened skirt, are not approved. Stud sleeve anchors are also not approved because they have exhibited large displacements in the *Translab* tests.

Under certain conditions, Resin Capsule Anchors (as discussed in a later section) may also be used as an alternative to MEAs.

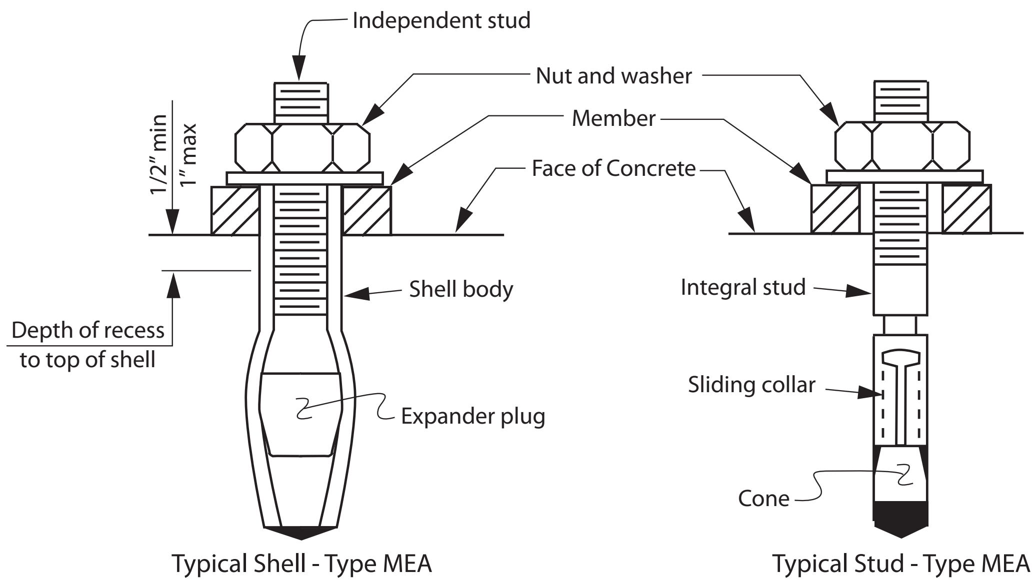

Figure 3.1-1 Common Types of MEAs

3.1.1 Resistance (Design Strength)

Generally, expansion anchors that are loaded in tension fail by initial slipping followed by concrete cone failure. The tensile resistance (design tension strength) of a MEA is based on its creep performance rather than the yield strength of the material. This design strength corresponds to a sustained tension load, that will cause the anchor to slip at a higher rate as the load increases, multiplied by a resistance (strength reduction) factor of 0.5 .

Table 3.1-1 lists the shear and tensile design strengths of shell and stud-type MEAs.

The design strengths listed in Table 3.1-1 are valid for the following conditions:

a) For static load conditions only.
When dynamic loading governs or for critical applications such as installations

over traffic, CIP anchors should be the preferred option. If CIP anchors cannot be provided, then Resin Capsule Anchors or bonded anchors may be considered.

b) For normal weight concrete having f'_c = 4000 psi.
For other concrete strengths, multiply the values in the table by:

$$\frac{(f'_c)\ actual}{4000}$$

c) For an edge distance of $6d_h$ or greater (where d_h is the hole diameter and is considered equal to the nominal diameter of the anchor plus 1/8").

Edge distance can be reduced down to $3d_h$ if the design strength is also linearly reduced to 50%. An edge distance of less than $3d_h$ is not recommended.

d) For a center-to-center spacing between anchors of $12d_h$ or greater (i.e., 100% effective). This spacing can be reduced down to $6d_h$ if the design strength is linearly reduced to 50% of that shown in Table 3.1-1.

e) When multiple anchors are used to hold an attachment.

If a single MEA is used to hold an attachment, then the design strengths shown in 3.1-1 should be reduced by 50%.

f) When an anchor is subjected to combined tension and shear loading, the following equation should be satisfied:

$$\frac{Factored\ shear\ load}{Factored\ shear\ resistance} + \frac{Factored\ tensile\ load}{Factored\ tensile\ resistance} \leq 1$$

Table 3.1-1 Factored Resistance (Design Strength) for Shell and Stud-Type MEAs

Stud Diameter (inches)	Shear Strength (kips)	Tensile Strength (kips)
1/4	0.4	0.4
3/8	0.8	1.0
1/2	1.5	1.1
5/8	2.1	2.1
3/4	2.4	2.4

3.1.2 Design and Detail Guidelines

The Designers should consider the following issues when MEAs are selected:

a) The Plans should show the size of MEA required, but not show the depth or the diameter of the hole – the size of the hole is addressed in the *Standard Specifications*. Figure 3.1.2-1 shows a typical detail for MEAs to be used in the Plans.

b) The thickness of concrete, where an anchor is embedded should be adequate to resist driving forces during anchor seating – typically, the minimum concrete thickness should be 1.5 times the depth of embedment.

c) To ensure proper seating of shell type MEAs, the top of the shell body is typically recessed between 1/2" and 1" below the concrete surface, and an independent threaded stud rather than a headed bolt is required.

d) As the design strength of shell and stud type MEAs is governed by creep considerations, the maximum anchor size is limited to 3/4 inch.

e) In corrosive environments, use other anchorage systems. While there are no pre-approved MEAs for this environment, stainless steel MEAs should be considered on a job-by-job basis.

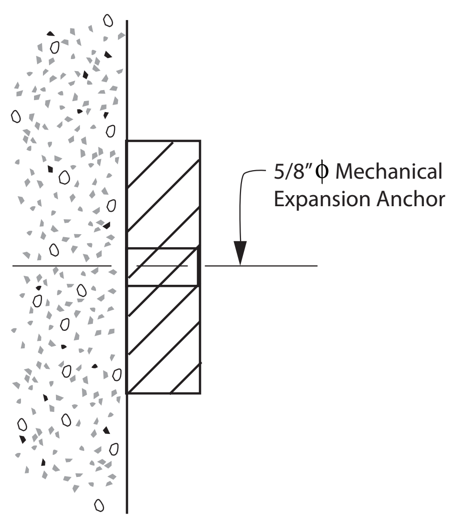

Figure 3.1.2-1 Typical Detail for MEAs

3.2 Bonded Anchors

Bonded anchor systems include the following:

a) Drill and Bond Dowel: Magnesium phosphate (mag-phos) is used as a bonding agent (see Section 51 of the *Standard Specifications*).

Mag-phos concrete hardens or cures in about three hours and does not require any special treatment during curing. It also develops full strength in three days. Mag-phos has the following advantages:

- Has relatively high tensile strength
- Has quick setting time
- Exhibits minimal shrinkage.

Mag-phos has the following disadvantages:

- Can not come into contact with zinc, aluminum, copper or cadmium (e.g., Mag-phos cannot be used for galvanized anchors)
- Is not likely to be fully effective in cracked concrete

b) Drill and Grout Dowel: Neat portland cement paste (grout) is used as a bonding agent (see Section 51 of the *Standard Specifications*).

Generally, cement grout is less expensive than mag-phos concrete, but cures more slowly. Grout has to be cured for at least three days during which time the dowels should not be disturbed. The grout normally develops 50% of its strength in three days, and reaches full strength in about 28 days. In addition, grout has a tendency to shrink – leading to cracks.

c) Drill and Epoxy Bond Dowel: Bulk epoxy is used as the bonding agent.

This method of bonding anchors to concrete is no longer used in structural applications as several bulk epoxies exhibit high creep characteristics under sustained tensile loads. In addition these epoxies may require exact mix ratios and are sensitive to freeze/thaw conditions.

d) Drill and Bond Dowel (chemical adhesive): A chemical adhesive or a cartridge epoxy is used as a bonding agent (see Section 51 of the *Standard Specifications*).

The advantages of chemical adhesives include:

- Higher viscosity (than mag-phos or grout) that helps the adhesive to be retained in a drilled hole
- Relatively quick setting time
- Low shrinkage

One of the disadvantages of this system is the need for stringent quality control and quality assurance testing, particularly since creep deformations can be a concern.

The chemical adhesives in drill and bond applications must be pre-approved and listed under the "*Authorized Material List*" prior to use on Caltrans' projects.

Bonded anchors provide a simple, effective, economical and preferred system for attaching metal fixtures or new concrete to existing/hardened concrete. In this system, bar reinforcement dowels or threaded rods are placed in drilled holes filled with either grout or a bonding material. Typically, bonded anchors are used for attaching new bridge barriers, sign frames or electroliers onto existing bridge decks, widening bridge abutments and bridge decks, and in seismic retrofits.

3.2.1 Applications

Typical applications of different types of bonded anchors are discussed in the following:

a) In general, drill and grout, drill and bond or drill and epoxy bond dowels should be used only in holes drilled at a downward angle of at least 20 degrees to the horizontal – generally detailed as a 3:1 slope on Plans.

b) Drill and Bond (Chemical Adhesives) dowels should be used when a drilled hole at a 3:1 slope cannot be achieved. In horizontal holes, chemical adhesives should always be used since the adhesives have a higher viscosity (example: in deck overhangs where horizontal holes may be the only option due to small deck thickness). This anchorage system is not recommended for use in overhead applications.

c) In general, drill and bond dowels should be used only in applications where tension is the primary force in the anchor; grouting, with bonding as an option, should be used when shear is the primary anchor force.

d) The use of bonded anchor system is not recommended where seismic ductility is critical (such as in seismic critical elements).

e) Proportioning, mixing, and hole preparation for grouting are more critical than those for other types of bonding. Therefore, the resistance (strength reduction) factor (ϕ) for a grouted anchor is larger than that for other types of bonded anchors.

3.2.2 Resistance (Design Strength)

The recommendations for the use of different types of bonded dowels and their design strengths are based on various pullout tests performed at the *Translab* (Abid A. Mir and John P. Dusel, 1993). Tables 3.2.2-1 and 3.2.2-2 list the factored resistance (design strengths) of Drill and Grout dowels as well as Drill and Bond dowels (both mag-phos and chemical adhesive) based on the *Translab* tests.

The resistance of bonded anchors under all limit states are determined as described below:

a) Resistance (design strength) in tension is smallest of the following:

- A short-term static load that causes an anchor slip or a movement of 0.01 inch.
- A short-term dynamic load that causes an anchor slip or a movement of 0.02 inch.
- ϕ * (theoretical yield strength of the anchor), where $\phi = 0.5$ for grouted anchors and 0.75 for bonded anchors.

Note: For the design parameters shown in Tables 3.2.2-1 and 3.2.2-2, the tensile strengths of rebar (both grouted and bonded) as well as those for grouted anchor rods are controlled by anchor slip while the tensile strengths of bonded anchor rods are controlled by yielding of anchor.

b) Shear Resistance (V) is determined as follows:

- When the minimum edge distance to the anchor is at least $10d_b$ (d_b is the nominal anchor diameter), then,

  $V = \phi$ * (0.55 * yield strength of anchor); $\phi = 0.8$

  This value of shear strength is the upper bound value for all types of bonded anchors.

- For drill and bond dowels, when the edge distance is less than $10d_b$:

  $V = 1.4\pi\sqrt{f_c'}\,d_e^2 \le$ [ϕ* (0.55 * yield strength of anchor)]

  $\phi = 0.8$

For drill and grout dowels, V is calculated using the same equation above, but the value of d_e cannot exceed $8d_b$. Tables 3.2.2-1 and 3.2.2-2 have been developed for f_c' = 4000 psi.

In the shear strength equation based on edge distance shown above, V is in pounds (lb), the edge distance d_e is in inches (in.) and the concrete strength f_c' is in psi. A factor of 0.7 is incorporated into this equation.

c) Edge distance that is smaller than the minimum edge distance shown in Tables 3.2.2-1 and 3.2.2-2 is not permitted.

d) When an anchor is subjected to combined tension and shear loading, the following equation should be satisfied:

$$\frac{Factored\ shear\ load}{Factored\ shear\ resistance} + \frac{Factored\ tensile\ load}{Factored\ tensile\ resistance} \le 1$$

Table 3.2.2-1 Factored Resistance (Design Strength) for ASTM A 706 Rebars (Grade 60)

Rebar Size	Minimum Edge Distance-d_e (inches)	Minimum Embedment Depth-l_e (inches)	Hole Diameter (inches)		Design Strength for Minimum d_e and l_e (kips)			Design Shear Strength (kips) ($d_e \ge 10\ d_b$)
					Tension		Shear	
			Grout	Bond	Grout	Bond	Grout and Bond	Grout and Bond
#5	3	5	7/8	1 1/8	3.1	10.5	2.5	8.2
#6	4	6	1	1 1/4	4.4	14.8	4.5	11.6
#7	4	7	1 1/8	1 3/8	6.0	20.3	4.5	15.8
#8	5	8	1 1/4	1 1/2	7.9	26.7	7.0	20.9

Table 3.2.2-2 Factored Resistance (Design Strength) for ASTM A 307 Threaded Rods

Anchor Size (inches)	Minimum Edge Distance-d_e (inches)	Minimum Embedment Depth-l_e (inches)	Hole Diameter (inches)		Design Strength for Minimum d_e and l_e (kips)			Design Shear Strength (kips) ($d_e \geq 10\ d_b$)
					Tension		Shear	
			Grout	Bond	Grout	Bond	Grout and Bond	Grout and Bond
5/8	3	5	7/8	1 1/8	2.3	6.1	2.5	3.6
3/4	4	6	1	1 1/4	3.3	9.0	4.5	5.3
7/8	4	7	1 1/8	1 3/8	4.6	12.5	4.5	7.3
1	5	8	1 1/4	1 1/2	6.1	16.3	7.0	9.6

3.2.3 Design and Detail Guidelines

The Designers should consider the following issues when drill and bond dowels are selected:

a) The Plans should show the type of the anchor [e.g., Drill and Bond Dowel (Chemical Adhesive)], the anchor size and the embedment depth required. The Plans should not show the diameter of the hole – this information is addressed in the *Standard Specifications*. Figure 3.2.3-1 shows typical details for a drill and grout dowel that can be used in the Plans.

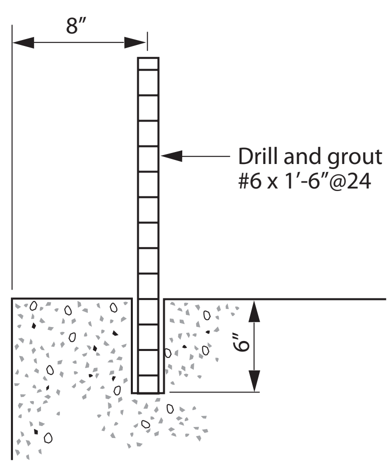

Figure 3.2.3-1 Typical Detail for Grouted Anchor

b) The embedment depths listed in Tables 3.2.2-1 and 3.2.2-2 are not necessarily sufficient to develop the yield strength of the anchor. Deeper embedments may provide the required ductility under certain conditions. Generally, holes having two times the minimum embedment depth for reinforcement bars or one and one-half times the minimum embedment depth for threaded rods will likely develop the yield strength of an anchor. Other potential failure modes such as concrete cone failure or concrete shear failure have to be considered when a deeper embedment is provided.

c) For anchors spaced closer than two times the embedment length, the concrete strength may control the design due to overlapping of the failure cones (see Figure 3.2.3-2). The design strength, based on the concrete strength and the surface area of the failure cone is calculated as follows:

- Tensile design strength (lb):

  $\phi\ [\ 2\sqrt{f_c'} * (\ \textit{surface area of the failure plane})\ ]$,

  where, f_c' is the concrete strength (in psi) and $\phi = 0.9$.

- Shear design strength (lb): 0.5 * [Tensile design strength]

For multiple anchors, the design strength corresponds to the lower of the two values – those based on cone failure or those obtained from Tables 3.2.2-1 and 3.2.2-2. Any acceptable method (such as that based on ACI 318-08) may also be used to calculate effective surface area of a failure plane.

d) In corrosive environment, stainless steel anchors should be considered. Galvanized anchors should not be used with mag-phos concrete.

See Memo to Designers 9-3 for additional examples on the use of Anchors.

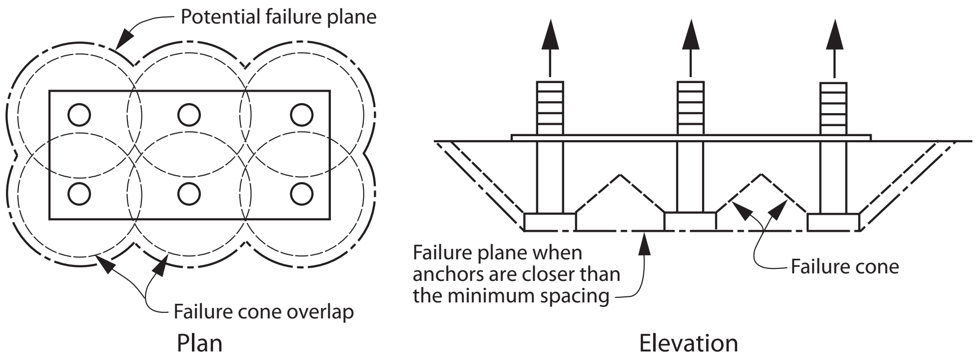

Figure 3.2.3-2 Effect of Anchor Group

3.3 Resin Capsule Anchors

A Resin Capsule Anchor (RCA) is a special type of a bonded anchor used to bond a threaded rod or a rebar into hardened concrete. RCAs are typically used in-lieu of MEAs. They can also be used in-lieu of "Drill and Bond (Chemical Adhesives)" anchors only if they conform to all the test requirements specified for a chemical adhesive as discussed in Section 3.2.1.

The RCA system is composed of a two-chambered glass/foil capsule that contains the resin and the catalyst (hardener). The size of a capsule depends on the size of the anchor. The capsule is inserted in a clean, pre-drilled hole of proper size. Next, a chisel-pointed threaded steel rod or rebar is attached to a roto-hammer and power driven to the bottom of the hole. This process will break the capsule and mix its contents. The mixed resin compound forms a strong waterproof bond with both the embedded anchor and concrete.

RCAs can be loaded sooner compared to other bonded anchors because of their short cure times. In general RCAs can be used in a wide variety of applications including in corrosive environments, or where dynamic loading is present. They are not recommended for use under water or where fires are likely to occur.

Unless approved by the State Bridge Engineer, the use of RCA in an overhead application is not permitted.

3.3.1 Resistance (Design Strength)

The design strengths of RCAs are based on limited pullout tests performed at the *Translab* (Abid A. Mir and John P. Dusel, 1993) as well as data furnished by the manufacturers in the testing program.

The factored resistance (design strengths), summarized in Table 3.3-1, are based on the following criteria:

a) They are controlled by creep deformations (for creep limits, see Section 75, *Standard Specifications*), and include a resistance factor (strength reduction factor) of 0.33, both for tension and for shear.

b) They are based on tests using ASTM A 307 threaded rods as anchors; these strengths may also be used for other types of anchors that have a higher strength.

c) The anchors are assumed to be subjected to static load conditions only. When dynamic loading (moving loads, vibratory loads etc) governs, the resistances listed in the table should be multiplied by 0.5.

d) They are valid for a concrete strength (f_c') of 5000 psi. For f_c' other than 5000 psi, the anchor strength is obtained by multiplying the values listed in Table 3.3.1-1 by the following factor:

$$\sqrt{\frac{(f_c')\ actual}{5000}}$$

e) They are valid for concrete temperatures up to 70 °F. At a temperature of 120 °F, the design strengths reduce to approximately 75% of those shown in the table. For intermediate temperatures, the design strengths should be computed through linear interpolation. However, RCAs are not recommended where the ambient temperature is likely to exceed 120 °F.

f) They are applicable when the center-to-center distance (spacing) between the anchors is at least equal to its standard embedment length. Spacing can be reduced to half the standard embedment depth only if the design strength in the Table is multiplied by 0.5. For intermediate spacing, linear interpolation may be used.

g) They are applicable when the edge distance to the anchor is at least equal to its standard embedment length. The edge distance can be reduced to half the standard embedment depth only if the design strength in the Table is multiplied by 0.7. For intermediate edge distance, linear interpolation may be used.

h) When combined shear and tensile loading is present, the following equation should be satisfied:

$$\frac{Factored\ shear\ load}{Factored\ shear\ resistance} + \frac{Factored\ tensile\ load}{Factored\ tensile\ resistance} \leq 1$$

If necessary, the designer may refer to the Caltrans' "*Authorized Materials List*" and review manufacturer's brochures to get an updated estimate of design strengths. The capacities should not exceed the strength shown on the manufacturer's data sheet multiplied by a reduction factor of 0.33.

Table 3.3.1-1 Factored Resistance (Design Strength) for Resin Capsule Anchors

Anchor Size (inches)	Minimum Embedment Depth (inches)	Hole Diameter (inches)	Design Strength for ASTM A 307 Threaded Rods (kips)	
			Tension	Shear
3/8	3 1/2	7/16, 15/32	2.1	1.7
1/2	4 1/4	9/16	3.9	2.1
5/8	5	11/16, 3/4	5.8	2.7
3/4	6 5/8	7/8	8.6	3.1
7/8	6 5/8	1	10.8	8.2
1	8 1/4	1 1/8	13.0	9.6
1 1/4	10 1/4	1 1/2	22.8	15.8

3.3.2 Design and Detail Guidelines

The Designers should consider the following issues when RCAs are selected:

a) The Plans should call out the anchor as Resin Capsule Anchor and specify the anchor diameter. The size of the hole and anchor embedment are addressed in the *Standard Specifications*.

b) RCAs should be installed in hardened concrete that is at least 28 days old.

c) RCAs should be installed in dry holes only. The installation temperature should not exceed the maximum installation temperature recommended by the manufacturer.

d) Typically, the anchor embedment as specified by the manufacturer will develop the strengths shown in Table 3.3.1-1. However, to develop the yield strength of the rod and ensure a more ductile performance, the depth of embedment should be increased to about twice that shown in the manufacturer's data (and this increased depth should be shown on Plans). Two resin capsules for bonding longer anchors in deeper holes may be required. In such cases, the strength of an anchor based on concrete failure should be verified. Deep holes that require more than two standard capsules to fill should not be used.

e) In corrosive environments, galvanized or stainless steel threaded rods should be used.

3.4 Summary

Table 3.4-1 summarizes the typical applications for different types of bonded anchors in concrete.

Table 3.4-1 Summary of bonded anchor applications

Hole Orientation	**Preferred Anchor Type**	**Comments**
Hole angle greater than 20 degrees (to horizontal) generally detailed as a hole at a 3 to 1 (minimum) slope	Drill and Bond Dowel or a Drill and Grout Dowel	Both RCA and Drill and Bond (chemical adhesive) may also be used but may not be cost-effective
Horizontal hole	Drill and Bond Dowel (chemical adhesive)	Resin Capsule Anchor may also be used
Vertically overhead hole	Resin Capsule Anchor	Prior Approval from the State Bridge Engineer is required

4. Rock Bolt Anchors

Rock bolts are commonly used to anchor or tie attachments to rock foundations. Short rock bolts can also be used to anchor into concrete where large tensile loading is expected.

Rock bolt anchorage systems exhibit ductile failure and low creep rate, but the costs are relatively high.

Figure 4-1 shows the engineering details of a rock bolt anchor. These details are based on tests performed by the Office of Structural Materials, METS at the *Translab* (J. P. Dusel et al, 1979). This figure shows an expansion shell type anchored rock bolt where the bolt is placed inside a cored hole and then rotated. The rotation pulls a wedge into an expansion shell, which expands against and into the wall of the cored hole. The void between the bolt and the cored hole is then grouted.

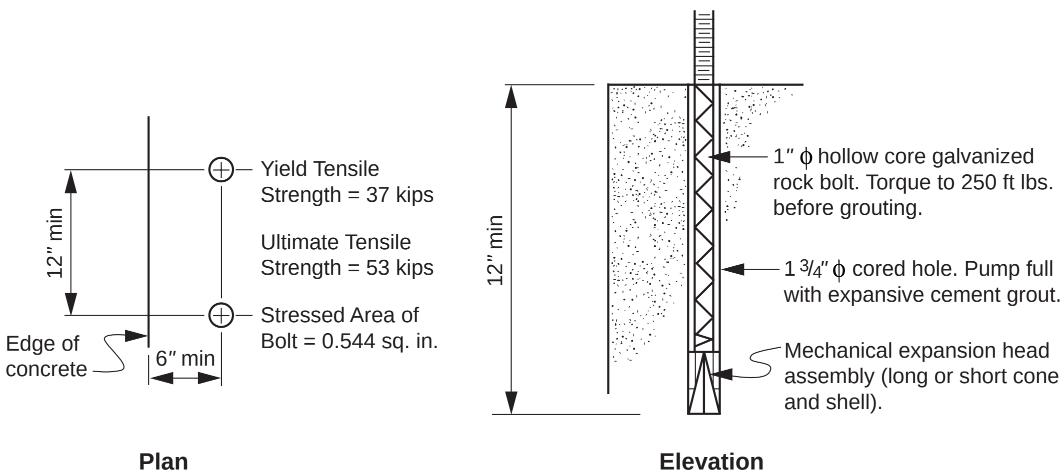

Figure 4-1 Rock Bolt Anchor

5. Cast-In-Place Anchors

5.1 Cast-In-Place Bolts or Headed Studs

Cast-in-place (CIP) bolts include common bolts, hooked bolts, headed bolts and studs welded to plates. Such anchors are best suited for attaching metal or precast elements to structural concrete such as for attaching base of message signs to concrete foundations and columns to substructures/foundations.

The design strength of an anchor system is affected by parameters such as bolt diameter, embedment depth, edge distance and the spacing between the anchors (Figure 5.1-1).

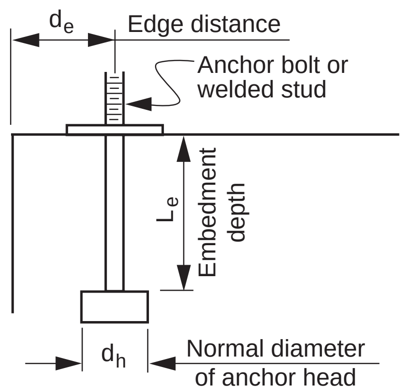

Figure 5.1-1 Typical Anchor Bolt

In general, common bolts are designed to have full embedment in order to develop the yield strength of the anchor steel and ensure a ductile failure. However, the designer may choose to use a shorter (partial) embedment (due to limited concrete thickness). In the case of partial embedment, the capacity of the concrete "failure cone" may limit the anchorage design strength (Figure 5.1-2). Concrete failures are generally brittle in nature.

Stud-welded plate anchors are comprised of steel plates that have either headed stud anchors or hooked bars. These anchors develop strength through bond and/or bearing.

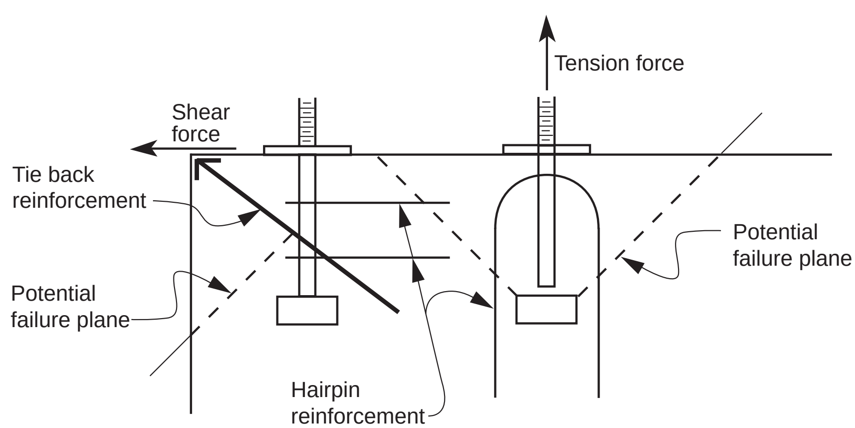

Figure 5.1-2 Typical Partial Embedment Failure Planes and Reinforcement

5.1.1 Resistance (Design Strength)

The design strengths of CIP anchors are summarized in Table 5.1.1-1 and are derived using ACI 318-08, Appendix D. Table 5.1.1-1 also lists the design parameters, including the minimum recommended edge distance, the minimum embedment depth to develop the ultimate strength of a single anchor, and the tensile and shear design strengths based on the full embedment condition.

The factored resistances (design strengths) shown in Table 5.1.1-1 are based on the following criteria:

a) The design strength of concrete is assumed as 3600 psi. The design strengths of bolts shown in Table 5.1.1-1 may also be used for higher concrete strengths, unless more updated strengths are required.

b) The tensile and shear strengths are shown for single anchors. For anchors in a group, group effects should be considered per ACI 318-08.

c) Case 1 and Case 2 values for the tensile strength of bolts apply to bolt types other than “J” bolts. Case 3 applies to “J” bolts. For shear strength, there is no such distinction between “J” bolts and other types of bolts.

d) Case 1 values for the design strength of bolts are controlled by the minimum edge distance and Case 2 values assume that the edge distances are greater than or equal to 1.5 times the minimum embedment depth. When the edge distance is between these two extreme values, then anchor strength should be calculated per ACI 318-08.

e) The anchor strengths in Table 5.1.1-1 are based on cracked concrete. If the design engineer determines that the concrete in which the anchors are installed will remain uncracked during service conditions, then the design strength shown in Table 5.1.1-1 may be multiplied by 1.40.

f) When combined shear and tensile loading is present, the following equation should be satisfied:

$$\frac{Factored\ shear\ load}{Factored\ shear\ resistance} + \frac{Factored\ tensile\ load}{Factored\ tensile\ resistance} \leq 1$$

Table 5.1.1-1 Factored Resistance (Design Strength) for Cast-In-Place ASTM A 307 Anchor Bolts

Bolt Diameter (inches)	Minimum Edge Distance (inches)	Minimum Embedment Depth (inches)	Tensile Strength (kips)			Shear Strength (kips)	
			Case 1	Case 2	Case 3	Case 1	Case 2
1/2	2 1/2	4	3.3	7.3	2.3	0.8	1.1
5/8	3	5	4.5	11.3	2.8	1.1	1.7
3/4	3	6	5.3	14.8	5.1	1.2	1.8
7/8	4	7	7.3	18.7	5.9	2.0	3.0
1	4	8	8.1	22.8	9.1	2.1	3.2

5.1.2 Design and Detailing Guidelines

a) The Plans should show the diameter of the anchor bolt, its embedment depth and the desired nut/washer combination if required.

b) Where possible, supplementary "hairpin" or tie back reinforcement should be detailed on Plans (Figure 5.1-2). This reinforcement will help to prevent sudden concrete cone or side blow-out failures.

Where larger size bolts under lateral loading are used, such as steel superstructure to concrete substructure connections, refer to the publication "*Lateral Resistance of Anchor Bolts Installed in Concrete*" (R. A. Swirsky et al, 1977).

5.2 Cast-In-Place Inserts

CIP Inserts are prefabricated metal devices with female threads which are specifically made for attachment of bolted connections (Figure 5.2-1). Such inserts, which are commercially available, are simple and easy to use in construction. Other advantages include the following:

- They are relatively inexpensive
- They can be attached to the forms prior to concrete placement without the need to drill holes in the forms
- These inserts will not extend outside the forms

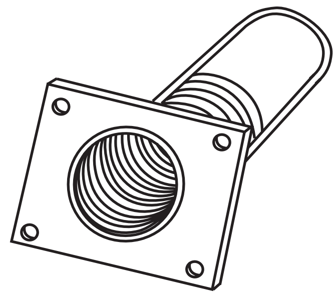

Figure 5.2-1 Ferrule Loop Insert

The primary disadvantage of such inserts is the location of the inserts and the attachments need to be precisely established before concrete is placed.

CIP inserts may be used for either temporary or permanent applications. Such applications include overhead signs and fixtures, safety railings, inspection ladders and falsework to concrete connections.

CIP inserts should meet the requirements of Section 75 of the *Standard Specifications*. Tensile design strengths for various sizes of inserts are listed in Table 5.2-1 and include a resistance factor of 0.7.

The Plans should identify the location of the CIP insert and indicate the diameter of the bolt or threaded rod be associated with the insert.

Table 5.2-1 Tensile Factored Resistance (Design Strength) for Cast-In-Place Inserts

Bolt Size (inches)	Design Strength (kips)
1/2	3
5/8	4
3/4	4.6
7/8	6.3
1	6.3

6. References

1. R. A. Swirsky, J. P. Dusel, W. F. Crozier, J. R. Stoker and E. F. Nordlin, 1977, *"Lateral Resistance of Anchor Bolts Installed in Concrete"* , Report No. FHWA-CA-ST-4167-77-12.

2. J. P Dusel, J. H. Andersen and J. R. Stoker, 1979, *"Evaluation of Rock Bolts for Installation in Existing Concrete"*, Report No. FHWA-CA-TL-79-03.

3. John P. Dusel and Craig N. Harrington, 1986, *"Evaluation of Mechanical Expansion Anchors – Vol. 1 & 2"*, Report No. FHWA/CA/TL-86/09.

4. Abid A. Mir and John P. Dusel, 1993, *"Evaluation of New Bonding Materials for Anchoring Dowels in Existing Concrete"*, Report No. FHWA/CA/TL-93/11.

5. ACI 318-08, Building Code Requirements for Structural Concrete.

6. Caltrans, (2008 & 2011). *California Amendments to AASHTO LRFD Bridge Design Specifications, 4th Edition,* California Department of Transportation, Sacramento, CA.