Chapter 4: Reinforcement

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4-1 Introduction

Concrete is known for being strong in compression but weak in tension. To withstand tensile stresses, structural concrete members are typically designed with reinforcement. Reinforced structural concrete can incorporate various materials to provide a composite material with higher tensile and shear capacity compared to unreinforced concrete. Some specialized materials used for reinforcement include polymer microfibers and fiberglass rods. However, the term “reinforced concrete” generally refers to concrete incorporating bar reinforcement (also known as bar reinforcing steel or rebar). In some cases, welded steel wire reinforcement, placed in specific patterns and locations within a concrete structure, may be specified for concrete reinforcement.

This chapter primarily covers bar reinforcement and its installation, focusing on contract requirements and best practices for installation. It highlights the types of inspections Structure Construction (SC) staff are expected to conduct. Additional guidance can be found in *Construction Manual*, Section 4-52, *Construction Details – Reinforcement,* and SC’s *Outline of Field Construction Practices*.

4-2 Technical Resources

Bridge Construction Memo (BCM) 52-1, *Reinforcement – General,* and its accompanying attachments provide supplemental information to the topics presented in this chapter. The attachments include rebar details such as radius, hook, and bend lengths, as well as bar reinforcement identifications. The radius and hook details in the BCM 52-1 attachments conform to the *Building Code Requirements for Structural Concrete* published by American Concrete Institute (ACI), otherwise known as *ACI 318*. Unless different details are shown on the project plans, *ACI 318* governs. The latest version of *ACI 318* can currently be downloaded by SC staff through the Engineering Workbench[1] by Accuris (account setup and login required). Instructions on using this resource can be found on the SC webpage under the “Field Resources”[1] tab.

The Concrete Reinforcing Steel Institute (CRSI) has issued various publications related to the design, fabrication, and installation of reinforcement that SC staff may find useful, including the *Manual of Standard Practice* and *Placing Reinforcing Bars*. CRSI also has a mobile application, *CRSI Rebar Reference*, that the Department currently has available to download for Department mobile devices.

These and similar resources provide best practices and valuable information. However, the *Contract Specifications* and contract documents govern if any contradictory information is presented.

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4-3 Contract Requirements and Preparation

The primary requirements for bar reinforcing steel incorporated into reinforced concrete are found in *Contract Specifications,* Section 52, *Reinforcement*, although other related specifications can be found throughout the *Contract Specifications*. The Contractor, or more specifically, the reinforcement subcontractor, is responsible for detailing, fabricating, and delivering rebar to the jobsite.

Source inspection and release by Materials Engineering and Testing Services (METS) is not usually required for typical rebar. For this reason, rebar delivered to the jobsite must be accompanied by a certificate of compliance (COC) in accordance with *Contract Specifications*, Section 52-1.01C(3), *Reinforcement – General – Submittals – Certificates*, and Section 6-2.03C, *Control of Materials – Quality Assurance – Department Acceptance – Certificates of Compliance*. File the COC in the job files as directed in the *Construction Manual,* Section 6-203D, *Sampling and Testing – Field Inspection and Release by the Resident Engineer*. Additionally, the Contractor must submit copies of the certified mill test reports (CMTR) and reinforcement lists. A CMTR, also known as a “mill cert”, is a document from the mill providing information regarding the physical and chemical properties of the steel and traceability of the material’s origin. A reinforcement list, also known as “bar list”, is a bill of materials for delivered rebar. It lists, among other information, the rebar sizes, lengths, and quantities delivered. Remind the Contractor of their requirement to provide these documents before rebar is scheduled for shipment. This responsibility is often overlooked because rebar procurement is typically the responsibility of a subcontractor.

Rebar incorporating additional fabrication processes usually requires METS inspection and release at the fabrication facilities to ensure contract compliance, including the following items listed below:

- Epoxy-coated and galvanized bar reinforcing steel
- Headed bar reinforcement
- Butt spliced bar reinforcing steel.

Mechanical butt splices may be fabricated in the shop or in the field. The contract requirements are the same in either case, but the coordination between METS and SC is different, depending on where the splicing is performed. To ensure consistency, SC staff should discuss the field operations with the METS Representative (METS Rep) and coordinate their assistance as needed.

Contract Specifications, Section 6-1.06, *Control of Materials – General – Buy Clean California Act* (BCCA), identifies the types of projects that are subject to the Buy Clean California Act; for additional information, refer to Public Contract Code Sections 3500-3505. The BCCA came about to help control emissions related to the fabrication of construction materials. For the types of projects identified in the aforementioned specification, carbon steel rebar must be sourced from a BCCA compliant mill that is on the Department's Authorized Material List (AML), Environmental Product Declarations (EPD). Verify that the rebar source is listed in the AML when reviewing the Form CEM-3101, *Notice of Materials to be Used,* submitted by the Contractor. Additionally, once rebar is delivered to the site, check that the Contractor has reported the material quantity delivered on the Data Interchange for Materials Engineering (DIME) webpage for the project within 5 business days. Refer to *Construction Manual*, Section 3-606, *General Provisions – Control of Materials – Buy Clean California Act*, for additional guidance.

Contract Specifications, Section 52-1.01C(2), *Reinforcement – General – Submittals – Shop Drawings,* requires the Contractor to submit temporary support system shop drawings with supporting design calculations for their proposed means of supporting any unsupported portion of reinforcing steel assembly that is greater than 20 feet. Typically, a column guying plan is used as a temporary support system plan. As part of its review, verify the guying plan addresses every stage of construction until the column is self-supporting. The guying system may be in one configuration for securing the column rebar cage itself, then be modified for placing and securing the formwork for the column, then modified yet again for access during concrete placement. Once the column concrete has gained enough strength to support itself without formwork, it is considered self-supporting. However, it is important to consider whether any unusual conditions, such as a very tall column pinned at its foundation or exposed to high winds, would require the guying system to remain in place. Refer to SC's upcoming *Temporary Structures Manual,* Chapter 5, *Guying Forms and Rebar Assemblies*, for specific guidance on reviewing and authorizing a column guying plan.

Unless specified otherwise, the Contractor is not required to submit any type of rebar shop drawing (sometimes known as placing drawings) or work plan for authorization. However, it may be a good idea to conduct a cursory review of rebar placing drawings generated by their rebar supplier or contractor to check that they align with the project plans, particularly for structures with complex rebar details.

Preparation for reinforcing steel fabrication and installation is not limited to just being familiar with applicable specifications, but also being aware of, and reducing the potential for, constructability issues. For instance, confirm that the rebar fabricator and detailer are mindful of features of the bridge that may affect rebar details. As mentioned in Chapter 2, *Preconstruction Planning*, some examples of features shown in the project plans that may cause errors in detailing and fabrication include varying girder spacing, varying section depths and girder heights, varying section thicknesses, skewed features at bents and abutments, and tightly curved or highly superelevated decks. Varying girder heights and section depths may require variations in rebar length. It is unlikely the Contractor will attempt to fabricate each stirrup to a specific length according to its exact location along the girder length. Rather, they may propose a simplified alternative. The Structure Representative must review and authorize any such proposal. The Contractor may propose to fabricate in blocks of equal length for installation in specific locations along the girder length, or stirrups may be fabricated in pieces for assembly in the field with varying lengths of lap splices to make variation in the overall stirrup length.

4-4 Construction

4-4.01 Shipment

As mentioned previously, the Contractor is required to submit COCs, CMTRs, and a bar list for each rebar shipment. These documents are often accompanied with the actual shipment. Check that the field delivered rebar matches these submitted documents. The bar list can be used to assist SC staff with inspecting rebar placement and determining quantities for progress payments.

4-4.02 Material and Fabrication Verification

Verify the sizes, steel type (or ASTM designation), and grade (or yield strength) of rebar match those shown in the project plans and *Contract Specifications*. Bars are required to have marks identifying these characteristics. These marks are usually embossed, or rolled-in, along one side of the bar. Figure 4-1 shows identifying marks on a specific bar.

Figure 4-1. Bar Reinforcement Identifying Marks

In the United States, a mark of a single number indicates its size. For the bar shown in Figure 4-1, the number “11” indicates a #11 sized bar (this corresponds to approximately 1.41 inches in diameter, as U.S. sizes are identified in eighths of an inch). The type of steel is identified by another symbol or marking, based on instruction provided in the applicable ASTM Specification. For bars complying with ASTM A706, the ASTM instructs to use the letter “W” as a mark. Similarly, ASTM A615 instructs to use the letter “S”. The bar shown in Figure 4-1 is marked with “SW”, signifying that it complies with both ASTM specifications. A separate number identifies its grade, such as the marking of “60” shown in Figure 4-1. This indicates Grade 60 steel for a minimum yield strength of 60,000 psi (the absence of a grade mark identifies Grades 40 or 50 steel). A separate mark identifies the mill where the bar was fabricated. A legend of mill identification marks can be found in CRSI’s *Manual of Standard Practice.* For the bar in Figure 4-1, the check mark and “Z” marks identify that the bar was fabricated at CMC Steel in Arizona. BCM 52-1, Attachment 2, *Identification of Reinforcing Steel Bars,* provides further guidance for identifying bar reinforcement.

Additionally, verify that bar lengths and bends conform to the project plans. Bar reinforcement bends and hooks must conform to the provisions of the *Building Code Requirements for Structural Steel* published by the American Concrete Institute (ACI). BCM 52-1, Attachment 1, *Reinforcing Steel Hook Detail*, contains standard hook details that align with ACI guidelines. Most bars will arrive at the jobsite having already been bent or cut at the fabricator’s facility, although there may be some cases when these fabrication processes occur in the field.

Ironworkers commonly use a rebar bending hand tool, often called a “hickey”, to adjust the position of and bend bar reinforcement in the field. A hickey is typically made of a long-handled steel rod with a curved bending head at the end. Ironworkers can bend rebar by fitting the bending head around the bar, and then applying their leverage on the handle to force the bar to bend. If the Contractor chooses to field bend bar reinforcement for hooks, verify the hooks are bent to the minimum required bend diameter, which is a function of the rebar size. Per *ACI 318*, Section 26.6.3, *Bending*, preheating field-bent bars may be required. Regardless of where it occurs, reinforcing bars must not be damaged during bending or cutting. As mentioned later in this chapter, the only epoxy-coated reinforcement that is allowed to be field bent is reinforcement complying with ASTM A775/A775M.

4-4.03 Placement

To perform as intended, reinforcement must be placed in accordance with the contract documents. Bar reinforcement placement requirements are found in the project plans and *Contract Specification*s, Section 52-1.03D, *Reinforcement – General – Construction – Placing*.

The duration of rebar placement may vary based on the complexity and size of the component being constructed. It can range from a brief operation to an ongoing task of several weeks. Therefore, close coordination and cooperation with the Contractor and the ironworkers, especially the foreman, are crucial to ensure timely inspections and to verify that the work is completed correctly and efficiently, minimizing the need for rework.

Discuss the construction schedule with the Contractor to ensure benchmark[1] inspections are performed before moving to the next stage of construction. An example of a benchmark inspection of bar reinforcement is inspection of a lower mat of rebar before the Contractor begins installing the upper mat. Ironworkers often use their own rebar placing drawings, developed from the contract documents, to place rebar. As mentioned earlier, although it is not mandatory for rebar shop drawings to be submitted, it is good practice for the SC staff to request a courtesy copy.

Be mindful of potential conflicts between reinforcement and items that are to be embedded in the structure (e.g., prestress hardware, utilities, drainage systems, etc.). If significant adjustments or relocation of reinforcement are necessary to resolve the conflict, discuss the situation with the Bridge Design (BD) Project Engineer.

4-4.03A Spacing, Clear Distance, and Cover

Contract Specifications, Section 52-1.03D, *Reinforcement – General – Construction – Placing,* defines the standard required minimum center-to-center spacing as 2.5 times the diameter of the larger bar for parallel bars. Additionally, the contract documents may specify the minimum clear distance. Be aware of the difference between center-to-center spacing, which measures the distance between the centers of the bars, and clear distance, which refers to the distance between the outer surfaces of the bar and adjacent bar or object.

The clear distance requirement for bundled bars – individual bars tied together in a group – depends on several factors, including the size of the concrete aggregate, bar diameters, and number of bars in the bundle. The previously mentioned specification outlines the clear distance requirements for bundled bars based on the factors listed above. For example, Table 4-1 is a summary of the minimum clear distance requirements for bundled bars based on the contract requirements for concrete with a maximum aggregate size of 1.5 inches.

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Table 4-1. Bundled Bar Clear Distance for 1.5-inch Aggregate Concrete

Bar Size	Dia. (in.)	Clear Distance (in.)		
		Single	2-bar Bundle	3-bar Bundle
#3	0.375	2.25	2.25	2.25
#4	0.500	2.25	2.25	2.25
#5	0.625	2.25	2.25	2.25
#6	0.750	2.25	2.25	2.25
#7	0.875	2.25	2.25	2.25
#8	1.000	2.25	2.25	2.60
#9	1.128	2.25	2.39	2.93
#10	1.270	2.25	2.69	3.30
#11	1.410	2.25	2.99	3.66
#14	1.693	2.54	3.59	N/A
#18	2.257	3.39	4.79	N/A

Note: Assumed for 1.5-inch diameter maximum aggregate

The concrete clear cover, or the clear distance between the outermost rebar and its adjacent concrete surface, is typically 2 inches minimum, unless specified otherwise. For instance, cast-in-drilled-hole (CIDH) concrete piles require at least 3 inches of clear cover. Projects within marine environments and freeze-thaw areas may specify greater cover.

Oftentimes, ironworkers will mark where rebar will be placed on the forms, as shown in Figure 4-2. If possible, check these layout marks before rebar is placed, and resolve any concerns with the Contractor.

Figure 4-2. Bar Reinforcement Layout

Contractors use spacers to meet the various spacing and cover requirements. The most common type of spacer is the precast mortar block, often referred to as “dobies.” During fabrication, tie wire is cast into the dobies, which are used to secure dobies to rebar. The dobies shown in Figure 4-3 are being used to meet cover requirements for the bottom mat of reinforcement.

Figure 4-3. Concrete Dobies Under Approach Slab Bottom Mat

Less frequently used, but still acceptable, are ferrous metal chairs. They are typically used for supporting the bottom mat of rebar for footings and slabs. Unless exceptions are specified elsewhere in the contract documents, *Contract Specification*s, Section 52-1.03D does not allow the use of aluminum, plastic, or wood spacers and supports. One exception is plastic spacers for CIDH piles, which are allowed under *Contract Specifications*, Section 49-3.02B(8), *Piling – Cast-In-Place Concrete Piling – Cast-In-Drilled-Hole Concrete Piling – Materials – Spacers*. Refer to BCM 49-3, Attachment 6, *CIDH Concrete Piling – Materials,* for additional information regarding the use of plastic spacers for CIDH piles.

When verifying spacing and cover, also measure the size of the spacers to confirm they are correctly sized to provide the required space. Take into consideration that rebar may move out of its current position and even bend when it is loaded during concrete placement. Additional spacers may need to be installed if this is a concern.

4-4.03B Tying

A set of bar reinforcement tied together in a grid-like fashion is known as a rebar mat. Similarly, rebar tied to form a framework, in the shape of a box or cylinder, is known as a rebar cage. Rebar is typically tied together when bars are in final placement, although some rebar are delivered with bars tied at the fabricator. Rebar cages for CIDH piles are an example of the latter.

Rebar must be installed in a way that ensures it remains in its intended position and retains its planned configuration during concrete placement. Tying bars securely is crucial for achieving this goal. Ironworkers use tie wires, usually 16.5 gauge, to fasten rebar at their intersections. While not every intersection needs to be tied, the frequency of ties should be sufficient to keep the rebar stable as intended. The *Contract Specifications* may define the frequency of tying. For example, column and pile rebar cages that are at least 4 feet in diameter have minimum tying frequencies specified in *Contract Specifications*, Section 52-1.03D, *Reinforcement – General – Construction – Placing*. Also, the ties for bundled bars must be spaced not more than 6 feet apart. There are also extra requirements for tying epoxy-coated rebar, including requirements for the tying material, as discussed in Section 4-5.01, *Epoxy-Coated Reinforcement*, of this chapter. The column reinforcement shown in Figure 4-4 is tied so that the vertical and hoop bars are secured together.

Figure 4-4. Column Reinforcement Ties

Check that rebar is held firmly in position by attempting to move it out of position by hand. Rebar in areas subject to heavy foot traffic may require additional tie wiring and more focused inspection to ensure it remains in place. Tack welding crossing bars is not recommended, as the properties of the bar reinforcement can be negatively affected.

4-4.03C Surface Cleanliness

To function as a true composite material, the bond between reinforcement and concrete must be secure and continuous such that the steel cannot slip relative to the concrete. For this reason, the rebar must be incorporated into the concrete free of surface contaminants or defects that could degrade the efficacy of the bond between the two materials. *Contract Specifications*, Section 52-1.03B, *Reinforcement – General – Construction - Cleaning*, states that “reinforcement…must be free of mortar, oil, dirt, excessive mill scale and scabby rust, and other coatings that would destroy or reduce the bond.” Some of these items are clear, while others require some judgment and interpretation. It is always better to prevent contamination than attempting to address it later.

For rebar storage, it is good practice (although not contractual) for the Contractor to store rebar away from mud, grease, water, and other deleterious material that may attach to the rebar. If storing rebar on site, contractors typically keep the bundles elevated off the ground by placing them on wooden pallets and lumber. Epoxy-coated rebar has its own storage requirements, which will be discussed later in this chapter.

If form oil is present on the rebar surface, it can be removed by wiping with rags and solvent. Dirt, of course, is everywhere on a construction site where workers may be walking across or standing on rebars. Proper access must be provided to prevent tracking mud onto the rebar. The tracking of dirt can even take place during a concrete pour. Dirt is relatively easy to remove but be sure it isn't knocked or washed into another location where it can cause contamination with the concrete pour, such as into nearby forms.

Curing compound on rebar is another concern. Rebar can unintentionally be sprayed with curing compound because of over spraying from an adjacent concrete pour. This oftentimes occurs when rebar protrudes from a construction joint. That curing compound must be removed from both the concrete and the rebar before the subsequent pour. This can be done by abrasive blasting the affected area. However, if the rebar is epoxy-coated, abrasive blast cleaning is not recommended due to potential damage to the coating. The bar should instead be wiped clean immediately when the cure is applied. The better practice is to protect the rebar from overspray.

Rebar that is protruding from or adjacent to a pour can also accumulate concrete that has splashed onto or has been poured through the rebar. This too can be considered deleterious material. It should be removed during the pour while the contaminating paste is still wet. If the concrete cures on the rebar, it becomes difficult to remove. In addition to forming a weak bond, it can also reduce the required clearance between adjacent bars. This situation can lead to issues such as aggregate segregation, voids, or rock pockets in future pours.

4-4.03D Mill Scale and Rust

The removal of mill scale and rust is often a matter of judgment. Some mill scale and rust are inherent in the processes of manufacturing, handling, and storing rebar. They are generally considered non-detrimental to the bond between rebar and concrete. The specifications state that mill scale should not be "excessive" and rust not "scabby". Although there are no established standards for these terms, "scabby" suggests that there are flakes of rust or scale that can be peeled off the bar like a scab off a wound. In general, rust and mill scale are not excessive if the weight, dimensions, or cross section are not significantly compromised when removed by hand using wire brushes, and bars remain compliant with the applicable ASTM specifications. This is not to imply the remaining bars should then be cleaned, but rather that the bars are acceptable in their current condition. Figure 4-5 shows light rust on bar reinforcement that does not appear to have affected the weight or cross section dimension. Loose rust and other material that may affect concrete bond to rebar can be removed by lightly striking the bar with a hammer. They may also be removed during handling by the Contractor.

Figure 4-5. Light Rust on Bar Reinforcement

4-4.04 Safety

In addition to verifying the acceptability of reinforcement material and placement, verify that required safety measures are in place. The California Code of Regulations (CCR) Title 8, Chapter 4, subchapter 4, contains the Construction Safety Orders (CSO). Within the Construction Safety Orders, § 1712, *Requirements for Impalement Protection*, requires workers to be protected from potential impalement from projecting objects. For steel reinforcement, the CSO specifies the “guarding all exposed ends… with protective covers, or troughs.” This applies when workers are at grade and rebar extends up to 6 feet above grade or working surface.

Contractors commonly use Cal/OSHA approved manufactured caps and covers, such as plastic caps or steel troughs, for this purpose. Square protective covers must measure at least 4-inch by 4-inch, while round covers must have a diameter of 4 ½ inches. Square protective covers have been installed on the end of the bars shown in Figure 4-6 for impalement protection. Note that some of the caps have likely fallen off from the tops of the bars, which is common with these types of covers, especially if used on smaller sized bars.

Figure 4-6. Plastic Caps

Contractors may also use “job-built” protective covers constructed of “Standard Grade” Douglas Fir or stronger material. Within the Construction Safety Orders, Appendix C, Plate C-25, *Protective Troughs for Protruding Reinforcing Steel*, provides details for acceptable trough designs to be used for rebar that extends up to 6 feet. For taller rebar or troughs not conforming to *Appendix C,* Plate C-25, troughs must be designed by a California licensed engineer and may be subject to a drop test as specified in the CSO.

Personal fall protection or guardrails must be used where applicable, including where there is potential for falls of more than 6 feet. They may be used in conjunction with protective covers or troughs.

Circular bar reinforcement cages, such as those for CIDH piles and columns, have a potential to roll if laid on their sides, as the reinforcement shown in Figure 4-7. These cages should be wedged to prevent them from rolling.

Figure 4-7. Bar Reinforcement Cage Laid on its Side

4-5 Corrosion Protection

Corrosion is the deterioration of materials caused by chemical reactions between the material and the environment it is exposed to. Rebar is susceptible to corrosion if it is exposed to the environment long term. For this reason, rebar must be protected from water and salts in the environment. As mentioned earlier, at least 2 inches of concrete cover is typically required. Project plans may show a larger concrete cover for projects in harsh environments. The consequences of insufficient cover include rebar corrosion and concrete spalling, as illustrated in Figure 4-8.

Figure 4-8. Bar Reinforcement Rusting and Concrete Spalling on Barrier

In some harsher environments, supplemental protective coatings on the rebar may be required to aid in resisting rebar corrosion. Epoxy-coated reinforcement and galvanized bar reinforcement are two types of coated bars typically incorporated in Caltrans projects. Attaching galvanic anodes to rebar is another preventative measure that may be utilized. Refer to the Caltrans METS *Corrosion Guidelines* for further information regarding the corrosive process and various corrosion protection methods for reinforcing steel and other materials.

4-5.01 Epoxy-Coated Reinforcement

Epoxy-coated reinforcing bars are the most common corrosion-resistant bar reinforcement used in reinforced concrete. Protection is provided by the application of an epoxy resin layer, or coat, all around the bars. The contract requirements for epoxy-coated rebar are covered in *Contract Specifications*, Section 52-2, *Reinforcement – Epoxy-Coated Reinforcement and Epoxy-Coated Prefabricated Reinforcement.*

Epoxy coating is typically specified for barrier reinforcement on projects that are within 1000 feet of marine environments in accordance with *Memo to Designers (MTD)*, 10-6, *Use of Pre-Fabricated Epoxy Coated Reinforcement in Marine Environment*. If a project in such an environment does not contain this requirement, the issue should be discussed with the BD Project Engineer, as a change order may be necessary to include epoxy coating. Additionally, *Contract Specifications*, Section 52-2.02A(1), *Reinforcement – Epoxy-Coated Reinforcement and Epoxy-Coated Prefabricated Reinforcement – Epoxy-Coated Reinforcement – General – Summary,* calls for specific reinforcement to be epoxy coated for projects in freeze-thaw areas.

Epoxy-coated rebar requires additional time for processing, as it must be fabricated, shipped to a coating facility, and then coated before shipping to the jobsite. The Contractor should account for the additional time required for procuring coated rebar. Epoxy-coated reinforcement is usually inspected, tagged, and released for delivery to the jobsite by METS. A TL-0624, *Inspection Release Tag* ("orange tag") produced by METS should be attached to the released material along with COCs when delivered. The one instance when epoxy-coated reinforcement does not require the typical source inspection process is when the fabricator is included in METS Authorization to Deliver (AD)[1] program for the applicable epoxy-coated reinforcement specification. Discuss with the METS Rep if there is any question regarding source inspection.

There are two types of epoxy-coated rebar specified in the *Contract Specifications*:

1. Epoxy-Coated Reinforcement
   a. Complies with ASTM A775/A775M.
   b. May be cut and bent in the field as needed.
   c. Coating must be light green.
2. Epoxy-Coated Prefabricated Reinforcement
   a. Complies with ASTM A934/A934M.
   b. Bar is cut and bent to specified lengths and shape before being coated.
   c. Cannot be bent after coated.
   d. Coating must be gray or purple.

Figure 4-9 shows an approach slab being constructed with epoxy-coated reinforcement (green) complying with ASTM A775/A775M.

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Figure 4-9. Epoxy-Coated Reinforcement (Green)

Epoxy-coated prefabricated reinforcement (purple), with coating complying with ASTM A934/A934M, is being used for the concrete barrier shown in Figure 4-10.

Figure 4-10. Epoxy Coated Prefabricated Reinforcement (Purple)

Contract Specifications, Section 52-2.02, *Reinforcement – Epoxy-Coated Reinforcement and Epoxy-Coated Prefabricated Reinforcement – Epoxy-Coated Reinforcement,* and Section 52-2.03*, Reinforcement – Epoxy-Coated Reinforcement* *and Epoxy-Coated Prefabricated Reinforcement – Epoxy-Coated Prefabricated Reinforcement,* addresses the contract requirements for these two coating types. The former specification also addresses epoxy-coated wire reinforcing, which will not be discussed in this manual.

To provide the required long-term protection against corrosion, epoxy coating must have a uniform minimum thickness, be protected against damage in the field, and be free of skips and holidays. The Contractor must protect the coating at every stage of fabrication, shipping, storage, and placing (including concrete placement) until it is incorporated into the work.

The *Contract Specifications* reference ASTM A775/A775M and A934/A934M standards for epoxy-coated rebar. These standards include requirements for handling, inspection, and repair of the coating. The "Field Resources" tab on the SC Intranet Webpage contains a link to instructions[1] for accessing ASTM standards. SC staff should pay particular attention to the *Guidelines for Jobsite Practices* found in the Appendices to the referenced ASTM standards. *Contract Specifications*, Section 52-2.03C, *Reinforcement – Epoxy-Coated Reinforcement and Epoxy-Coated Prefabricated Reinforcement – Epoxy-Coated Prefabricated Reinforcement – Construction,* requires the Contractor to comply with these practices. It is important to discuss these practices with the Contractor before fabrication and delivery to ensure they are taking the necessary precautions with the material. The goal is to reduce the potential of extensive damage, which would either require extensive repairs or rejection of the material.

The following are examples of jobsite practices that the Contractor must follow as specified in ASTM A775/A775M and A934/A934M:

1. Handle with care to avoid abrasion. This includes padding contact areas of handling equipment and not dropping or dragging bars.
2. Store so that there is no contact with the ground. Support with wooden or padded supports, spaced to minimize sagging. Separate coated and uncoated steel reinforcing bars.
3. Minimize rehandling by either off-loading as close as possible to final placement or by placing under the crane so bars can be hoisted to final placement.
4. Avoid long-term storage onsite, including after installation and prior to fully incorporating into concrete. If stored outdoors for more than two months, take measures, such as providing an adequate cover, to protect the material from the effects of direct sunshine, salt spray, or any other contaminants.
5. Do not flame cut.
6. Tie with non-conductive tie wire, such as epoxy-coated or plastic-coated tie wire.

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7. During concrete placement, use vibrators with plastic or rubberized coatings. Do not permit vibrators to rattle on coated rebar. This may damage the rebar coating. Coated rebar will not be visible for inspection after concrete placement, so consolidation must be done correctly.
8. Provide walkways where necessary to prevent damage from foot traffic on installed rebar.

Be sure to inspect epoxy-coated rebar for damage to its coating during delivery and installation. Bars with more than 2 percent surface area damage to its coating must be replaced. Otherwise, damage can be repaired with patching material that is compatible with the existing coating. Figure 4-11 shows an example of damaged coating. Follow the manufacturer's recommendation for surface preparation, including removal of rust, and application of the patching material.

Figure 4-11. Damaged Epoxy Coating

Contract Specifications, Section 51-1.03D(4), *Concrete Structures – General – Construction – Placing Concrete – Construction Joints,* requires construction joints to be abrasive blast clean before placing the adjoining concrete. However, this may be an issue if the joint contains exposed epoxy-coated reinforcement, such as when epoxy-coated reinforcement is required for concrete barriers on bridge decks. As mentioned earlier, abrasive blast cleaning can potentially damage the coating. In such cases, discuss alternative methods for preparing the construction joint.

4-5.02 Galvanized Reinforcement

Galvanizing is another means of providing a protective coating around reinforcement. In this case, rebar is coated with a zinc layer. Galvanized reinforcement must be identified in the contract documents when required. Requirements for galvanized rebar are detailed in *Contract Specifications*, Section 52-3, *Reinforcement – Galvanized Bar Reinforcement.* Galvanized bar reinforcement has its own standards, ASTM A767/A767M, Class 1, that the Contractor must comply with.

4-5.03 Galvanic Anodes

Galvanic anodes protect against corrosion, mainly for reinforcement in existing structures. As such, they are typically specified for concrete repair and rehabilitation projects. Galvanic anodes function by taking on the corrosive process instead of the reinforcement, which is why they are sometimes called “sacrificial anodes”. Anodes typically have tie wires that allow them to be secured to reinforcement. They are installed at regular intervals, following spacing provided by the project plans or manufacturer’s recommendation.

4-6 Headed Bar Reinforcement

To function as designed, rebar must be securely bonded into concrete and anchored such that it can sustain loading to yield without pulling out of the concrete. This can be achieved by providing a hook on the terminal end of a bar or by continuing the bar into an adjacent component. However, there may be situations where these design considerations are not be feasible. For instance, in the former scenario, the additional length or terminal hook may create unacceptable rebar congestion. For the latter, an adjacent member may not be available. A commonly used solution for these issues is to utilize headed rebar, sometimes referred to as T-heads. The head secures the bar in place by bearing against the concrete as an alternative to a length of bar or bar hook.

Headed rebar is fabricated so that the end of the bar is larger than the diameter of the actual bar. This is frequently achieved by attaching a cap or plate to the end of the bar. Common methods for attaching the plate include welding and threading. Heads can also be forged onto the bar end itself.

Headed bar reinforcement manufacturers and products that are authorized to be used are listed in the AML. If headed rebar is required for the project, check that the products noted in the Contractor’s submitted Form CEM-3101, *Notice of Materials to be Used,* are on the AML. METS typically inspects headed rebar at the source, attaching a TL-0624, *Inspection Release Tag,* to the lot of headed rebar authorized for release and delivery to the jobsite. During installation, pay particular attention to the clearance and cover of the rebar heads. Even though they are usually incorporated to reduce rebar congestion, this issue may still be a concern (although to a lesser degree).

Figure 4-12 shows headed bar reinforcement installed at a hinge of a CIP (cast-in-place) concrete bridge.

Figure 4-12. Headed Bar Reinforcement

4-7 Splices

Project plans may detail reinforced concrete structure components and elements that require rebar longer than what can be fabricated or delivered at full length. In such cases, shorter lengths of rebar would need to be provided and installed in segments. Constraints such as limited access, tight formwork, or construction joints may also make the installation of full-length rebar impractical, thus requiring this approach. Regardless of the reason for installing rebar in segments, segments must be installed so that they act as single, continuous units. This can be achieved by splicing the rebar.

Splices can be divided into three functional categories: lap splice, service splice, and ultimate butt splice. These categories are based on the design criteria and location of rebar within the structure. *Contract Specifications*, Section 52-6, *Reinforcement – Splicing,* and subsequent subsections outline the contract requirements for splicing, including applicable testing and acceptance criteria.

All splices of adjacent rebar must be staggered. If installed within the same vicinity, splices may create a weak zone in the group of rebar. The required stagger length is dependent on the type of splice and bar diameter. The minimum staggered distance for all lap splices is the same length specified for the lap length. For butt splices, including those butt spliced per welding or mechanical means, the staggered distance is at least 2 feet between splice midpoints. Project plans may identify “No Splice Zones”, which are locations within the structure where splices are not allowed. Remember to document in the as-built project plans all ultimate butt splices (except for bar reinforcing hoops) and splices not placed per the project plans under BCM C-6, Attachment 3, *Guidance for Completing As-Built Project Plans*. Figure 4-13 shows staggered adjacent mechanical splices that are staggered approximately 2 feet.

Figure 4-13. Staggered Splices with Couplers

4-7.01 Splicing Methods

The typical methods of splicing rebar are lap splice, mechanical splice, and welded splice. The method used must conform to the contract requirements and depends on factors such as application and functional category.

4-7.01A Lap Splice

A lap splice is the most common means of splicing bar reinforcement. It involves overlapping, or lapping, the end portions of separate rebar segments to create a longer continuous line of rebar. The lapped sections must be in contact and securely tied with each other, with a clear distance of at least 2 inches between the spliced section and adjacent reinforcement or splices. As a category, lap splice does not have specified testing and acceptance requirements as opposed to service and ultimate splices.

For the splice to be considered continuous, the lap splice length for installed bars must meet the minimum length of lap specified in *Contract Specifications*, Section 52-6.03B, *Reinforcement – Splicing – Construction – Lap Splicing*. Lap length varies, depending on bar diameter, grade, and if rebar is coated and/or bundled. For instance, uncoated reinforcement complying with ASTM A615, Grade 60, requires a lap length of at least 45 times the diameter of the bar for no. 8 size bars or smaller. For nos. 9, 10, and 11 sized bars, the lap length is 60 times the diameter of the bar. If two different bar diameter sizes are lapped, the minimum length of lap for the smaller diameter bar governs. Table 4-2 summarizes the minimum lap splice length required for each type of non-epoxy-coated or galvanized reinforcement bar.

Table 4-2. Minimum Lap Splice Length

Inch-Pound Smaller Bar Size	Dia. (in.)	Minimum Lap Splice Length (in.)		
		ASTM (Grade): A615 (G60), A706, A1036	ASTM (Grade): A775, A934, A1055	ASTM (Grade): A615 (G40)
#3	0.375	16.88	24.38	11.25
#4	0.500	22.50	32.50	15.00
#5	0.625	28.13	40.63	18.75
#6	0.750	33.75	48.75	22.50
#7	0.875	39.38	56.88	26.25
#8	1.000	45.00	65.00	30.00
#9	1.128	67.68	95.88	50.76
#10	1.270	76.20	107.95	57.15
#11	1.410	84.60	119.85	63.45

Lap splicing is not allowed for no. 14 and no. 18 sized bars, as well as for all hoops.

Lap splicing can also be achieved using mechanical lap splice couplers. Mechanical lap splicing is similar to traditional lap splicing, where continuous bars are provided by lapping segment ends. The difference is that the lapping segments are attached mechanically using couplers. The manufacturer’s recommendation may require less overlap than traditional lap splicing. Mechanical lap splice couplers are subject to the requirements of mechanical splices.

Contract Specifications, Section 52-1.03D, *Reinforcement – General – Construction – Placing*, addresses the splicing of spiral reinforcement. Project plans sometimes include discontinuities in spiral column reinforcement at the column/soffit interface or the column/footing interface. This is to facilitate placing the main horizontal rebar for the footing or bent cap. Check the project plans for details at these types of discontinuities. They usually require spiral lap splices and either terminal hooks or mechanical lap splices.

4-7.01B Mechanical Splice (Coupler)

A mechanical splice uses a mechanical coupler, or coupler, to join two pieces of rebar. Couplers act by “gripping” the end of the two rebar mechanically, producing what would be considered a continuous bar.

The AML contains an assortment of commercially available couplers that are allowed to be used on Caltrans projects. Their means of mechanically connecting one bar to the other vary. Verify that couplers to be used are on the AML for steel reinforcing couplers. Witness that the Contractor’s operator, who must be prequalified and listed in the Contractor’s authorized splice prequalification report, installs couplers per the manufacturer’s recommendation. Figure 4-14 shows the installation of sleeve-lock shear bolts type mechanical couplers, and Figure 4-15 shows the installation of two-piece sleeve/forged end type mechanical couplers. Sampling and acceptance testing requirements depend on if the splice is considered a service splice or an ultimate splice and is discussed later in this section.

Figure 4-14. Sleeve-Lock Shear Bolt Mechanical Coupler Installation

Figure 4-15. Two Piece Sleeve/Forged End Mechanical Coupler Installation

Mechanical splices add an additional thickness to the original bar size. This must be considered when placing mechanically spliced rebar in its final location. For example, the clear spacing of the couplers shown in Figure 4-16 is questionable, as concrete may not be able to adequately surround the bars and couplers. This situation should raise concern and immediately be brought to the attention of the Structure Representative and Contractor; elevating it to the BD Project Engineer may be appropriate, to investigate an appropriate solution.

Figure 4-16. Congestion of Mechanical Couplers

The outer surface of the coupler must have at least 1-3/4 inches clearance from the concrete surface.

4-7.01C Welded Splice

A welded splice uses a welding process to splice rebar, typically connecting the butt-ends of rebar. The two butt-weld splicing methods discussed in the *Contract Specifications* are described below*:*

1. Resistance-Butt-Weld: A machine holds both ends of the hoop together and passes a large electrical current through the bar which creates enough heat to fuse the two ends together completing the process. This type of welding is not

covered by the American Welding Society (AWS) code and therefore does not require any of the Non-Destructive Testing (NDT) or Certified Welding Inspector (CWI) requirements. The *Contract Specifications*, Section 52-6.02B(1), *Reinforcement – Splicing – Materials – Service Splices and Ultimate Butt Splices – General*, requires the fabricator performing this splice be on the AML for resistance welding fabricators. This welding method is commonly used for rebar hoops, especially for cast-in-drilled-hole (CIDH) pile rebar and column cages.

2. Complete-Joint-Penetration (CJP) Butt-Weld: This type of weld uses a CJP groove weld complying with AWS D1.4 to join two butt ends together. The groove weld extends completely through the thickness of components joined. The primary purpose for using CJP groove welds is to transmit the full load-carrying capacity of the structural components they join. This welding method is commonly used for field splicing straight bars.

4-7.02 Service Splices and Ultimate Butt Splices

Service splices and ultimate butt splices are designed to higher standards than lap splices. As a result, there are specific testing and acceptance criteria for both service and ultimate butt splices (lap splices do not have such requirements). The key difference is that ultimate butt splices include additional testing criteria beyond those of service splices to ensure ductile behavior.

During the design phase, the BD Project Engineer must identify structural members that are supposed to be ductile and deform inelastically through several cycles during a seismic event, dissipate seismic energy, and sustain damage without significantly losing strength. These members are referred to as seismic critical members (SCMs). SCMs may be designed to force damage to occur at locations most accessible for inspection and damage assessment. Additionally, the BD Project Engineer must identify capacity protected members (CPMs). The forces transmitted from SCMs to adjoining CPMs are limited during a seismic event. CPMs stay mostly elastic with minimal damage to the member. Columns, shafts, and piles in soft or liquefiable soils are members that are commonly identified as SCMs. Common CPMs include footings, bent caps, abutment diaphragms, and girders.

For splicing rebar within SCMs, project plans will note that splices are not allowed, limit splice locations by noting a “No Splice Zone” at plastic hinge regions, or allow only ultimate butt splices. For splicing rebar within CPMs, project plans may identify a “No Splice Zone” within a critical zone and/or designate locations where service splices are acceptable. For any bridge member, if there is no such designation, then splices may be either service splices or lap splices. The exception is that if a butt-weld or mechanical splice is shown on the project plans without a designation, that splice must comply with service splice requirements.

4-7.03 Sampling and Testing – Service and Ultimate Butt Splice

The inspection, sampling, and testing of service splices and ultimate butt splices are very rigorous processes that require coordination among SC staff, METS, and the Contractor. The requirements for these processes are located in *Contract Specifications,* Section 52-6.01C, *Submittals*; Section 52-6.01D, *Quality Assurance*; Section 52-6.02B, *Service Splices and Ultimate Butt Splices*. The following sections detail as to what is involved with these processes and elaborate on these contract specifications.

4-7.03A Prior to the Start of Any Splice Work

4-7.03A(1) Preconstruction Meeting

Although not required by the contract, it's advisable to hold a preconstruction meeting with the Contractor to discuss the service and ultimate butt splice requirements. The sampling and acceptance criteria vary between these types of splices.

The Contractor should have their splicing Quality Control Manager (QCM), rebar subcontractor, and the representative for the Authorized Laboratory attend such a meeting. If possible, a representative from METS should also attend the preconstruction meeting. A suggested partial list of items to discuss at the preconstruction meeting includes:

1. Splicing QCM's responsibility to inspect the lots of splices for conformance with the specifications and manufacturer's recommendations prior to sampling.
2. Splice Prequalification Reports, production, and quality assurance (QA) sampling and testing requirements.
3. How samples of ultimate butt splices will be selected from a completed lot of splices that have been assembled for the final time.
4. The Contractor's method of designating and making the lots available for sampling.
5. The Department's method of random sample selection.
6. Labeling and shipping of the samples.
7. Result reporting, time allowed, and Department approval.

4-7.03A(2) Splice System Prequalification

Contract Specifications, Section 52-6.02B(1), *Reinforcement – Splicing – Materials – Service Splices and Ultimate Butt Splices – General,* requires that the material and, if applicable, welding fabricator for both service and ultimate splice systems be prequalified prior to use. The Contractor must select a splice system from the AML, specifically the *Caltrans Authorized List of Couplers for Reinforcing Steel*. If the proposed system is not on the prequalification list, contact the METS Rep to verify the latest approved splice systems.

4-7.03A(3) Splice Prequalification Report

The Contractor must submit a splice prequalification report for service splices and ultimate butt splices in accordance with *Contract Specifications*, Section 52-6.01C(6)(c), *Reinforcement – Splicing – General – Submittals – Qualification Statements – Splice Prequalification Report*. This report must include:

1. A copy of the coupler manufacturer's product literature giving complete data on the splice material and installation procedures.
2. Names of the prequalified operators who will be performing the splicing.
3. Descriptions of the positions, locations, equipment, and procedures that will be used in the work.
4. Certifications from the fabricator for operator and procedure prequalification including the certified test results from the authorized laboratory for the prequalification splice test samples. For each bar size of each splice type to be used, each operator must prepare two (2) prequalification splice test samples and two (2) additional prequalification splice test samples if using splices dependent on bar deformations.
5. Splice test samples that must have been prepared and tested no more than two (2) years before the submittal of the splice prequalification report. Splice test samples and testing must comply with the production testing requirements.

Forward a copy of the splice prequalification report to the METS Rep so that they can assist with its review.

4-7.03B Sampling and Testing Splices During Production

The sampling and testing of service splices and ultimate butt splices are somewhat similar. However, ultimate butt splices are critical to the structure’s seismic performance. Hence, the sampling and testing requirements for ultimate butt splices are more stringent compared to service splice requirements.

4-7.03B(1) Ultimate Splice Sampling Procedures

The Contractor’s splicing QCM must notify the Department when a designated lot of splices is complete and has been inspected. SC staff must collect four samples of production splices from each lot for testing.

Production sample splices are required to be randomly selected from a completed lot. Selecting from a completed lot means that samples will be removed after final splicing has been made. Splices that are unassembled for transportation or other reasons are not considered completed and would require resampling when assembled for the final time.

The intent of the ultimate butt splice specification is to sample splices as close as possible to the in-place completed work, which may or may not entail removing splices from bars after they have been tied in their final location. For example, if the main longitudinal reinforcement of a column rebar cage was spliced together and assembled on the ground prior to full height erection, the straight bar sample production splices could be selected prior to cage assembly. If splices are made vertically at the job site in or above their final positions for bar reinforcement of columns or CIP concrete piles, instead of removing the splice test samples from the completed column rebar cage, it is acceptable to prepare the samples as specified for service splice test samples, mimicking the field conditions, provided testing as specified for ultimate butt splices is performed.

Similarly, in most cases, the selection of production samples for welded hoops can be done prior to cage assembly.

All production sample splices removed from the work must be repaired or replaced. The Department does not require ultimate butt splice testing on repaired splices from a lot unless an additional ultimate butt splice test is required on the same lot of splices. If this additional test is required, the Department may select any repaired splice for the additional test.

Each sample must be at least 4 feet long for #9 and smaller rebar, and at least 6-1/2 feet long for #10 and larger rebar in accordance with California Test (CT) 670, *Method of Tests for Mechanical and Welded Reinforcing Steel Splices*.

4-7.03B(2) Service Splice Sampling Procedures

The *Contract Specifications* require the Contractor to prepare four splice test samples from each lot of completed splices. The service splice samples must be prepared in the same conditions as the production service splices. The same splice material, operator, location, equipment, position, and procedures must be used when preparing service splice samples. The sample length must be at least 4 feet long for #9 and smaller rebar, and at least 6-1/2 feet long for #10 and larger rebar in accordance with CT 670. Figure 4-17 shows splice test samples being prepared.

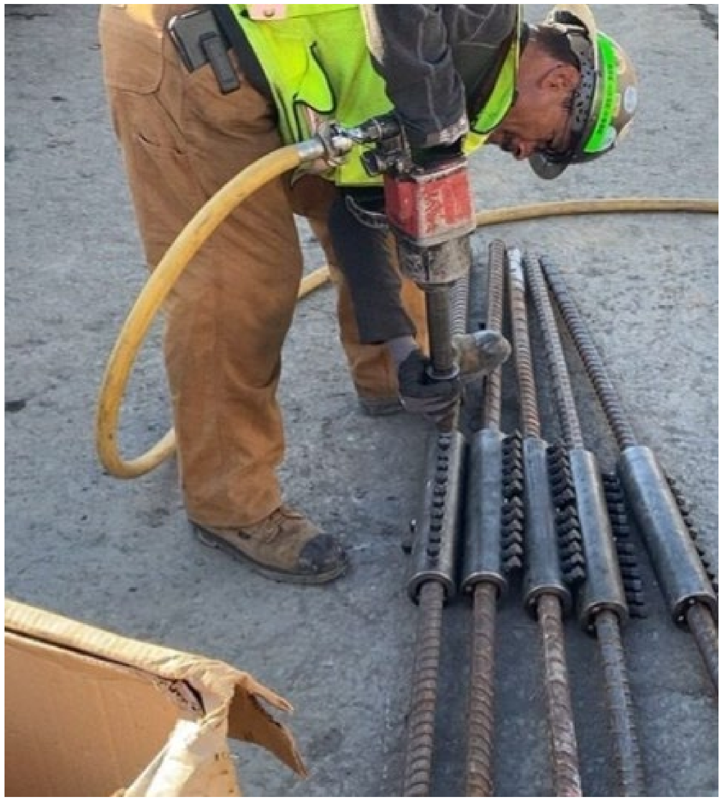


Figure 4-17. Splice Test Sample Preparation

4-7.03B(3) Quality Assurance Testing

Quality assurance (QA) testing is a requirement of the ultimate butt and service splice specifications. QA tests are always performed concurrently with the first production test. After the first QA test, at least one out of every five additional production tests (or portion of) thereafter will be accompanied by an additional QA test. Use a random selection method to designate both QA lots and QA sample splices. Table 4-3 illustrates the number of QA tests required for a given amount of splice lots.

Table 4-3. QA Test Requirement for Lots

Number of Lots	Number of Accumulative QA Tests Required
1	1
2-6	2
7-11	3
12-16	4
17-21	5
22-26	6

To obtain samples for the QA test, four (4) sample splices will be made concurrently with the production test samples. These sample splices do not have to be removed from a completed lot of splices.

The Contractor may encase splices in concrete before receiving notification of the QA test results from the Department. However, the Contractor will not be relieved of the responsibility for incorporating material into the work that complies with the contract.

4-7.03B(4) Tamper Proof Markings and Sample Shipping

To ensure that the sample splices are not tampered with, all ultimate butt-splice samples (i.e., pre-job, production, and quality assurance) must have a tamper proof marking applied to them as required per *Contract Specifications*, Section 52-6.01D(3)(b), *Reinforcement – Splicing – General – Quality Assurance – Test Samples – Ultimate Butt Splice*. SC staff should apply the marking. Examples of tamper proof markings include:

1. Rubberized paint. This will show any re-gripping or disassembly of the splices. (See Figure 4-18).
2. A digital photo of the splice sent to the lab for comparison.
3. Alternative marking systems which can be considered with METS concurrence.

Figure 4-18. Tamper Proof Marking on Production Sample Splices

All samples must be identified pre-job, production, or job QA and be accompanied with Form TL-0101, *Sample Identification Card*. Create a sample record, generate the Form TL-0101, and assign testing using the Data Interchange for Materials Engineering (DIME) webpage. Figure 4-19 shows a Form TL-0101 that was generated on DIME for sample splices to be tested by METS. Coordinate the delivery of test specimens to the METS Laboratory or other authorized Department laboratory assigned to perform testing of mechanical and welded splices per CT 670. Discuss the method of shipment and other testing related questions with the METS Rep.

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION
SAMPLE IDENTIFICATION CARD
TL-0101 (REV. 02/17)
DIME Sample ID: 2023-11-06-9

SAMPLE SENT TO:	TEST TYPE:	FIELD NO.
☐ HDQRS. LAB		
☐ BRANCH LAB	SHIPMENT NO.	DIST LAB NO.
☐ DIST. LAB		
☑ TRANS. LAB	AUTHORIZATION NO.	LOT NO. L123-099-23
		P.O. OR REQ. NO.

SAMPLE OF:	#8 bar HRC 500-510 Couplers
FOR USE IN:	
SAMPLE FROM:	Fabricator
DEPTH:	
LOCATION OF SOURCE:	Integrity Rebar Placers

THIS SAMPLE IS SHIPPED IN(NO. CONTAINERS)	AND IS ONE OF A GROUP OF	SAMPLES REPRESENTING (TONS, GALS, BBLS, STA, ETC.)

OWNER OR MANUFACTURER: Integrity Rebar Placers

TOTAL QUANTITY AVAILABLE	TEST RESULTS DESIRED	DATE NEEDED
4 Couplers	☐ NORMAL ☐ PRIORITY	

REMARKS:

DATE SAMPLED:	11/06/2023	BY:	Osiell Ramirez
TITLE:	Quality Assurance Inspector ((916) 767-3535)		
DIST, CO, RTE, PM:	05-SB-217-0.9/1.4		
CONT. NO.:	DEA: 051C3604	FED. NO.:	ACNH-P217(003)E
LIMITS:	SANTA BARBARA COUNTY NEAR GOLETA FROM 0.2 MILE EAS		

RECIPIENT(S): (to be selected by data publishing engineer)

CONTRACTOR:

Figure 4-19. Form TL-0101, Sample Identification Card

When completing Form TL-0101, ensure that all items are completed. If incomplete, it could delay METS' ability to issue test results. Specific items to consider are:

1. Contact information for the person that did the sampling is needed to answer potential questions.
2. Include an email address in the remarks section; this is used by METS to expedite sending the test results.
3. Include with the couplers:
   a. A copy of the Material Test Report (MTR) for the heat number of the bar reinforcing steel
   b. The MTR for the lot number of couplers represented by the samples. METS cannot issue test results without this information.
   c. A copy of the certificate of compliance for the bar reinforcing steel represented by the samples.

METS cannot issue test results without this information.

4-7.03C Splice Acceptance Requirements

4-7.03C(1) Slip Test Requirement

Except for mechanical lap, welded, or hoop splices, one (1) of the four (4) splice test samples is tested for total slip. If the slip test result complies with the total slip value requirement specified in the aforementioned *Contract Specifications*, Section 52-6.02B(1), proceed to perform the tensile and/or rupture tests.

If the splice test sample exceeds the total slip value specified in the *Contract Specifications*, the three (3) remaining test samples are tested for total slip. If any of the three (3) remaining test samples exceed the specified total slip value, the Department rejects all splices in the lot.

4-7.03C(2) Other Requirements for Service Splice

Service splices must develop a minimum tensile strength of 80,000 psi. The acceptance criteria are described below:

1. If only one (1) splice test sample complies with the requirements, the Department rejects all splices in the lot.
2. If only two (2) splice test samples comply with the requirements, perform one (1) additional service splice test consisting of four new splice test samples on the same lot of splices. This additional test must consist of tensile testing four (4) splice test samples, randomly selected by the Department, and removed from the lot of completed splices. If any of the four (4) splice test samples from this additional test do not attain the specified minimum tensile strength, the Department rejects all splices in the lot.

3. If three (3) or more splice test samples comply with the requirements, the Department accepts all splices in the lot.

4-7.03C(3) Other Requirements for Ultimate Butt Splice

Ultimate butt splices must meet one of the following requirements:

- Rupture in the reinforcing bar outside of the affected zone and show visible necking as specified in CT 670, Necking (Option I).
- Rupture anywhere and neck as specified in CT 670, Necking (Option II).

The acceptance criteria are described below:

1. If only one (1) splice test sample complies with the requirements, the Department rejects all splices in the lot.
2. If only two (2) splice test samples comply with the requirements, perform one (1) additional ultimate butt splice test consisting of four new splice test samples on the same lot of splices. If any of these four (4) new splice test samples do not comply with the specified requirements, the Department rejects all splices in the lot.
3. If three (3) or more splice test samples comply with the requirements, the Department accepts all splices in the lot.

Figure 4-20 depicts terms used in CT 670. The bar shown in this figure would pass the tensile test for an ultimate coupler because the visible necking is outside the affected zone.

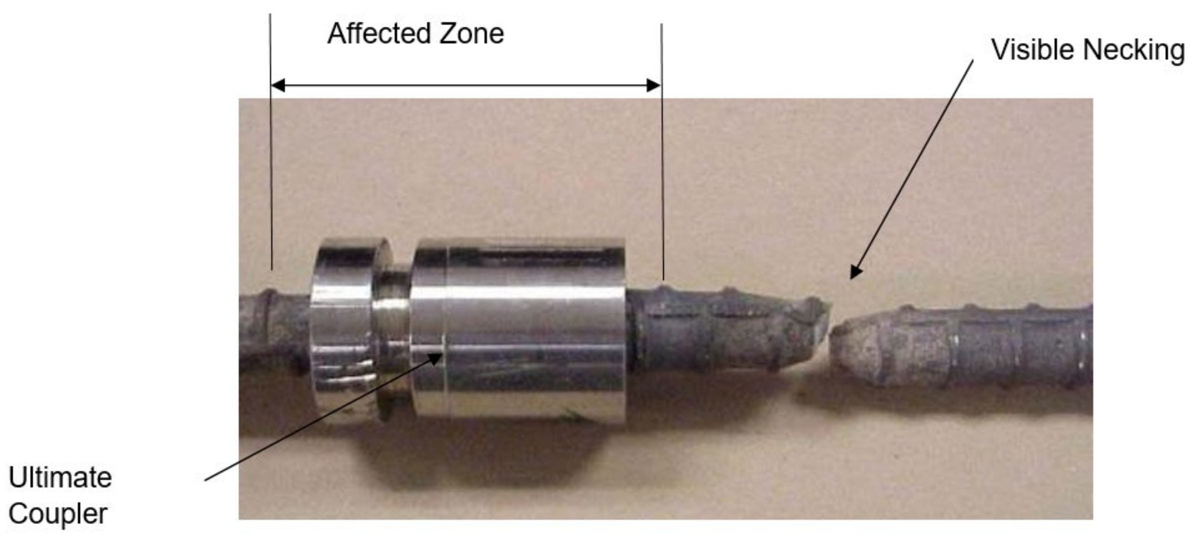
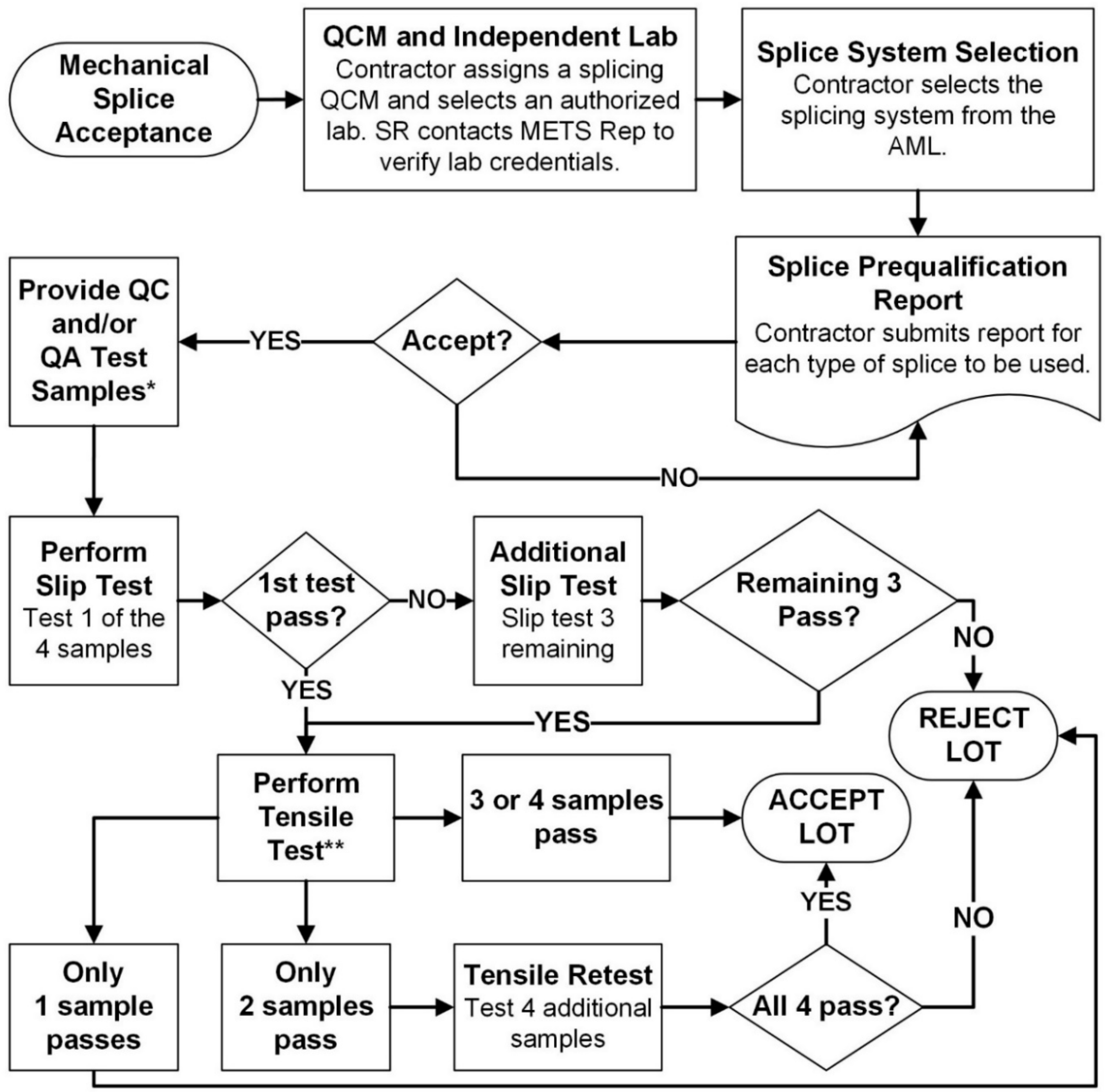


Figure 4-20. Passing Tensile Tested Ultimate Coupler

Figure 4-21 illustrates the mechanical splice acceptance procedure for QC and QA testing in a flow chart.



* **QC and QA Test Samples**

- QC: Four samples for each lot. Tested by authorized lab.
- QA: Four samples for 1st lot and every subsequent 5th lot (group). Tested by METS.

** **Tensile Test Requirements**

Service Splice

- Tensile strength: 80,000 psi

Ultimate Butt Splice

- Break outside affected zone; visible necking, **OR**
- Strain: ≥ 6% for ≥ #11 rebar; or ≥ 9% for ≤ #10 rebar

Figure 4-21. Mechanical Splice Acceptance Procedure Flow Chart

4-7.03D Review Time

The *Contract Specifications* include a review time for production and quality assurance tests. To avoid costly delays, it is important to respond to the Contractor in writing within the time allotted per the *Contract Specifications* as shown in Table 4-4.

Table 4-4. Review Time for Sample Tests

Sample Type	Review Time
Production Sample Tests	Three business days to review each production test report submitted by the QCM.
Quality Assurance	Three business days upon receipt of the samples by METS. Two extra business days per each simultaneous submittal.

4-7.03E After Completion of Splice Production Work

The Contractor provides the following submittals for Department's review:

1. Splice Quality Control Test Report
2. Splice Rejection Mitigation Report
3. Radiographic Film Developing Process Records (when welding is involved).

After completion and acceptance of the bar splices, ensure that the locations of the splices are noted in the as-built plans per BCM C-6, *Required Documents to be Submitted During Construction,* and that all the submittals and test reports are filed in the project records.

4-7.03F Testing Requirement Clarifications for Welded Butt Splices

The following clarifies test requirements for welded butt splices:

1. For Resistance-Butt-Welded splices (welded hoops):
   a. Slip test is not required.
   b. Destructive testing is required.
   c. Radiographic testing is not required.
2. For Complete Joint Penetration (CJP) butt-welded splices (except welded hoops):
   a. Slip test is not required.
   b. Destructive testing is required for both service and ultimate butt splices.
   c. Radiographic testing is not required whenever butt-welded splices are removed from a lot of completed splices (i.e., whenever they require replacement).

d. Radiographic testing is required whenever samples are prepared as described in the *Contract Specifications* (i.e., whenever they do not require replacement due to removal from a completed lot).

3. Refer to CT 670 regarding tensile test (destructive testing) requirements.

4-7.03G Items to Be Recorded in the Job Files

During the progress of the work, all splice documentation must be filed in Category 37, *Initial Tests and Acceptance Tests*, under the appropriate sub-category headings. Table 4-5 is an example of a summary record of production tests that SC staff can adopt for this purpose.

Table 4-5. Sample Summary of Record Production Tests

Model	Size	Sample Date	Description	Location	Number Used		Lot No.	QA Test	QC Test	Note
					This time	To date				
HRC 500XL/ 510XL	#9	10/1/24	Two Piece Sleeve/ Forged Ends	Bent 19 Column HOV	14	14	1	Pass	Pass	
				Bent 16 Column HOV	18	32	1			
HRC 500XL/ 510XL	#14	10/1/24	Two Piece Sleeve/ Forged Ends	Bent 19 Column HOV	92	92	1	Pass	Pass	
				Bent 16 Column HOV	100	192	1, 2	N/A	Pass	
HRC 410/420	#18	1/7/25	Sleeve-tapered thread	Bent 17 HOV	108	108	1	Pass	Pass	
Bar Grip XL	#14	1/19/25	Sleeve-tapered thread	Bent 3R middle CIDH pile extension	60	60	1			

4-8 Drill and Grout Dowels/Drill and Bond Dowels

"Drill and Grout Dowels", "Drill and Bond Dowels", and "Drill and Bond Dowel – Chemical Adhesive" are post-installed, non-mechanical methods used for embedding anchors, or dowels, into an existing structure. These techniques are often specified for projects that require a new concrete structure to either connect to an existing one or to a recently constructed concrete structure that lacks protruding reinforcement. Dowels are typically not specified for supporting sustained tension loads (*Structure Technical Policy*, 5.50, *Post-Installed Adhesive Anchors in Concrete*).

These methods typically involve drilling holes into the existing structure, cleaning the holes, filling those holes with a bonding material, and inserting dowels into the holes to a minimum specified depth. The tail ends of the dowels, which are not bonded to the existing structure, are then cast into the new structure. The post-installed dowels act to enhance the bond between the two separate structures. The required dowel material is specified in the contract documents and usually consists of reinforcing bars or threaded rods. The primary difference between the three methods is the bonding material required to fill the hole.

Contract Specifications, Section 51-1.03E(4), *Concrete Structures – General – Construction – Miscellaneous Construction – Drill and Grout Dowels,* specifies that grout be used as the bonding agent for the "Drill and Grout Dowels" method. Grout, as defined in *Contract Specifications*, Section 51-1.02G, *Concrete Structures – General – Materials – Grout,* is made of 4 gallons of water, at most, for every 94 pounds of cement (portland or portland limestone).

For the "Drill and Bond Dowels" method, the requirements for the bonding material to be used are specified in *Contract Specifications*, Section 51-1.02C, *Concrete Structures – General – Materials – Bonding Materials*. These include the same materials specified for rapid setting concrete.

Chemical adhesives are to be used for the "Drill and Bond Dowel – Chemical Adhesive" method. The AML lists chemical adhesive products that are authorized for use. It also notes the types and sizes of dowels that each product is intended to be used with. Additionally, refer to the AML for the permissible concrete temperature range for each adhesive product. Using a chemical adhesive outside its specified temperature range can negatively impact the performance. For instructions on product usage and installation, refer to the manufacturer's recommendations and the product's International Code Council Evaluation Service (ICC-ES) report, which documents the product's compliance with various building codes. The ICC-ES report number for each authorized chemical adhesive product can be found in the AML, and the reports are readily available online. Figure 4-22 shows reinforcement installed to an existing structure using a chemical adhesive.

Figure 4-22. Drill and Bond Dowel – Chemical Adhesive

SC staff must perform the following during inspection:

1. Verify that any loose, chipped, or spalled concrete has been removed and the holes are drilled into sound concrete.
2. Verify that the holes are drilled at the locations specified in the project plans. This is essential for maintaining proper edge distance and center-to-center spacing.
3. Check that the diameter of the drilled holes is correct by checking the drill bit size marked on the shank (see Figure 4-23). The required hole diameter is specific to the bonding material being used. Refer to the relevant specifications or, if applicable, the manufacturer's recommendations.

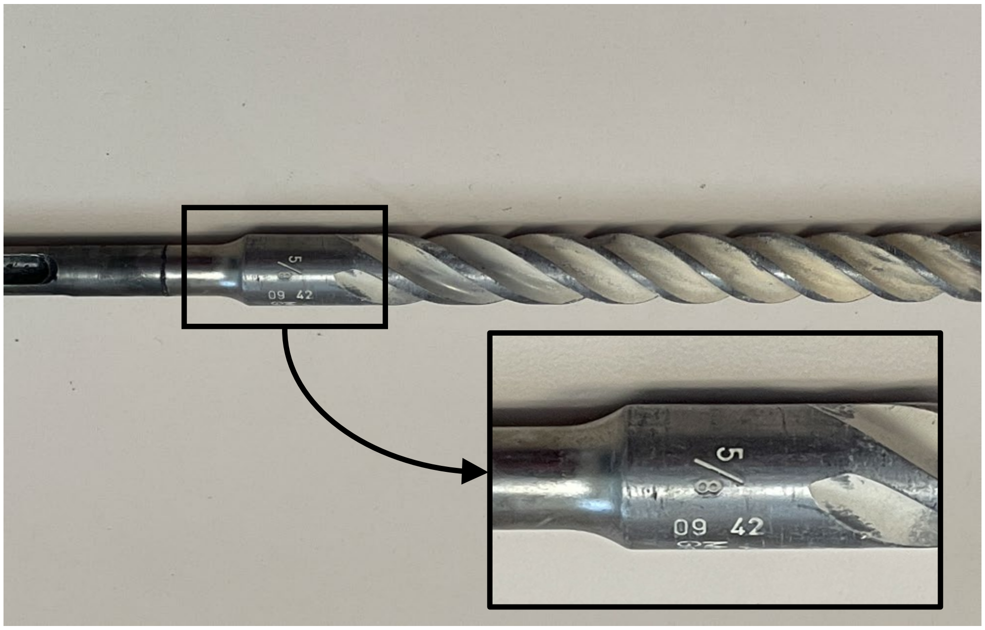


Figure 4-23. Diameter Size on Drill Bit Shank

4. Confirm that the holes are drilled to the depth indicated in the project plans. Over-drilling can create a through hole, which may allow the bonding material to drain away. Contractors often use tape on the drill bit to mark the desired depth (see Figure 4-24) or employ drill stops to limit the drill depth (see Figure 4-25).

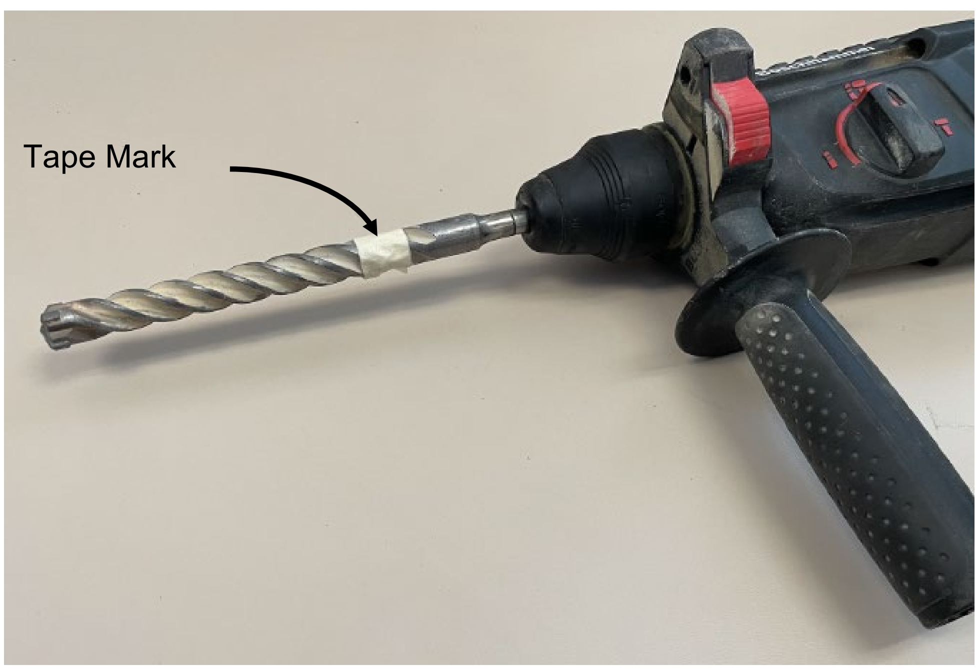


Figure 4-24. Drill Bit with Tape Mark

Figure 4-25. Drill with Drill Stop Attachment

5. After they are drilled, confirm that the holes are dry and clean. A clean hole is typically achieved by blowing compressed air into the hole, brushing the hole with a wire or nylon brush, and blowing compressed air a second time. Verify that the manufacturer's instructions for the specific adhesive are followed. Additionally, inspect the dowels to ensure they are clean and free of any oil or residue that might interfere with proper bonding.
6. After the bonding material is placed and the dowel inserted into the hole, verify that the hole is filled completely and that the level of the bonding material remains consistent over time. A stable level of bonding material indicates that the drilled hole is a blind hole and not a through hole. Through holes may be present due to over-drilled holes, voids in the concrete (such as in a voided slab), or utilities in the structure. Any changes in the level of bonding material should be investigated, with corrective action taken.

The various requirements for each method, including those not discussed above (e.g., hole size, curing method, etc.), are summarized in Table 4-6:

Table 4-6. Drill & Grout and Drill & Bond Requirements

	Drill and Grout Dowels	Drill and Bond Dowel	Drill and Bond Dowel-Chemical Adhesive
Contract Specifications (CS)	51-1.02G 51-1.03E(3) (drilling) 51-1.03E(4)	51-1.01C(3) 51-1.02C 51-1.03E(3)	51-1.01C(5) 51-1.01D(3)(c) 51-1.02H 51-1.03E(5)
Material Type	Portland Cement or Portland Limestone Cement	Rapid Setting Concrete: 1. Magnesium phosphate concrete 2. Modified high-alumina-based concrete 3. Portland-cement-based concrete	Chemical Adhesive
Material / Product Requirement	Grout (CS 51-1.02G)	Table in CS 51-1.02C	Authorized Materials List (AML)
Drilled Hole Size	Dowel Diameter + ¼ inches	Dowel Diameter + ½ inches	Per Manufacturer's Recommendation
Slope Limit for Horizontally Drilled Hole (Vertical/Horizontal)	1:3	1:3	No slope
Curing Method	Curing Compound Method or Kept Continuously Wet	1. Curing Compound Method: Modified High-Alumina-Based concrete, Portland-Cement-Based concrete 2. None: Magnesium Phosphate	Per Manufacturer's recommendation
Cure/Immobilization Time	3 days	3 hours	Per Manufacturer's Recommendation

Grout can only be used where specified. Do not allow the Contractor to substitute grout as the bonding material when “Drill and Bond Dowels” or “Drill and Bond Dowel – Chemical Adhesive” is specified. Grout does not provide as strong a bond as a rapid-setting material or chemical adhesive would provide.