Frequently Asked Questions (FAQ) About Mechanical Splices

Introduction

One common aspect of reinforced concrete construction is the need to splice reinforcing bars, whether it is to provide continuous reinforcement over a long expanse, to extend a reinforcing bar beyond where it currently ends, or to replace a section of in-place bar that has sustained damage. Splicing of reinforcing bars may be accomplished through the use of several methods, butt welding two pieces of reinforcement together, lapping two bars over a certain prescribed distance to transfer the force between the two adjacent bars by way of surrounding concrete, or by mechanical splice.

There are a wide variety of commercially available products used to mechanically splice two pieces of reinforcement together. CRSI publishes *Reinforcing Bars: Anchorage and Splices* which provides details to many of these available systems, most of which follow some form of the following methods for joining bars:

- Cutting or rolling threads onto a bar end and screwing them together with a threaded coupler
- Swaging or forging a coupling sleeve around the two bar ends
- Using a series of special shear screws embedded into the bar ends within the confined interior of a coupler
- Embedding the bar ends within a sleeve filled with metallic or cement grout

Most mechanical splice systems are designed to meet the requirements of governing codes. Mechanical splices that develop a code prescribed strength in tension and compression are often referred to as a “full mechanical splice”, however there are products on the market that are “compression only” splices.

CRSI regularly receives inquiries concerning various aspects of reinforcing bars, and reinforced concrete design and construction. Most of these questions are initiated by design professionals (engineers and architects) or field personnel (inspectors, code enforcement personnel, and contractors). This Technical Note presents a collection of typical questions that are asked regarding mechanical splices. It should be noted that typical mechanical splice questions vary by region, manufacturer, coupler type, and project type.

This report has been prepared to address questions related to mechanical splices when used in conjunction with the 2012 International Building Code [ICC 2012], Building Code Requirements for Structural Concrete (ACI 318) [2011], and Standard Test Methods for Testing Mechanical Splices for Steel Reinforcing Bars (ASTM A1034/A1034M) [2010]. Projects designed and built to other standards, such as Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary (ACI 349) [2006] or Department of Transportation requirements are not addressed in this document. For specific information regarding these types of projects, contact the manufacturers.

Frequently asked questions (FAQ) and responses are provided below.

General Information

What terminology is relevant to a mechanical splice?

As defined in ACI 116 [2005], a mechanical splice is “the complete assembly of an end-bearing sleeve, a coupler, or a coupling sleeve, and possibly additional intervening material or other components to effect a connection of [two] reinforcing bars.”

A mechanical splice is typically comprised of either a coupler or coupling sleeve as noted above. A **coupler** is a threaded device for joining reinforcing bars for the purpose of providing transfer of either axial compression or axial tension or both from one bar to the other. A **coupling sleeve** is a non-threaded device for joining reinforcing bars for the purpose of providing transfer of either axial compression or axial tension or both from one bar to the other. Both of these definitions are from ASTM A1034, which is introduced later herein.
Why are mechanical splices used?

There are a variety of reasons mechanical splices are used in reinforced concrete construction today. Some of them are as follows:

- **a) Congestion Mitigation** – Oftentimes, mechanical splices are used in structures where heavy reinforcement requirements will not physically allow placement of lap splices, as shown in Fig. 1.

- **b) Required by Design** – Certain designs, such as the splicing of #14 or #18 reinforcing bars, are required by Code to use mechanical or welded splices, as lap splices are not permitted.

- **c) Improve Structural Integrity** – Unlike lap splices, mechanical splices do not require bond with the surrounding concrete to achieve their strength, and thus they improve the structural integrity of any structure designed or anticipated to behave inelastically. In fact, lap splices tend to lose strength once the reinforcement begins to yield. This is due to the fact that once the reinforcing bar begins to yield, the bar begins to de-bond with the surrounding concrete, which permits slip to occur between the steel and concrete, thereby losing effectiveness.

- **d) Mitigate Formwork Damage** – Dowel bar mechanical splices can be used as an alternative solution to standard dowels and are shown in Fig. 2. By utilizing these devices, contractors can re-use forms on a job several times, which improves the construction economics. Dowel bar mechanical splices have also been used in recent years to speed up construction schedules on tall buildings using jump form techniques.

- **e) Jobsite Safety** – Most reinforced concrete construction jobsites can have exposed reinforcement protruding from the floors or walls of the structure. Figures 3(a) and 3(b) show two examples of protruding bars. These protruding bar ends can cause physical harm to on-site construction personnel even if highly visible, so mushroom-like bar covers are used. Mechanical splices can alleviate some of these concerns because they can sit flush with the concrete, eliminating the exposed reinforcement ends, as shown in Fig. 4.

Mechanical splices provide a versatile means for joining reinforcing bars. Are there any special applications that an engineer should be particularly aware of for design or retrofit applications?

Most mechanical splices join two reinforcing bars, in-air, prior to placing concrete around the bars. There are some special application splices which include the following:

- **Weldable Couplers** – One end of the coupler can be welded to a structural steel plate or shape (i.e. column, beam, pile), as shown in Fig. 5. In this example, the coupler is welded to a structural steel plate and a threaded reinforcing bar end is then inserted into the coupler awaiting for a future concrete member to be cast against the steel. There are other types of weldable coupler devices that do not require the bars to be threaded.
Figure 5 — Mechanical splices welded to structural steel plate.

- **Retrofit Work** — Oftentimes, relatively small areas of a concrete member are exposed or “opened up” to permit installation of a repair or structural retrofit, as shown in Fig. 6. These small areas do not always permit out-of-plane maneuvering room for the installation of extra reinforcing bars. Moreover, existing bars cannot be rotated or displaced laterally. Special mechanical splices have been developed for these applications.

Figure 6 — Mechanical splices used in retro-fit project to tie new reinforcement to existing in-place bars

- **Form Dowels** — Joining reinforcing bars through formwork at a concrete construction joint is common, as shown in Fig. 3a. Several manufacturers make a flush-mounted coupler with a flange that can be attached to formwork. After the formwork is stripped, a temporary protection cap is removed, exposing the female end of the coupler. A threaded reinforcing bar, or an externally threaded coupler component, is then inserted into the internally threaded exposed coupler end, and the reinforcing bar is made continuous across the construction joint.

Are mechanical splices manufactured from the same steel as the reinforcement?

Typically, mechanical splices are manufactured from higher quality steel, and sometimes have much higher yield and tensile properties than the reinforcing steel being spliced.

A design calls for the use of a specialty reinforcing bar to help mitigate potential corrosion. Are mechanical splices available with a protective coating or made from stainless steel?

Mechanical splices are available in black (plain), zinc-plated, epoxy-coated, or hot-dipped galvanized. The epoxy coating on the coupler conforms to ASTM A775 [2007a] requirements. Galvanized, mechanical splices meet ASTM A767 [2009b] or ASTM A123 or ASTM A153 requirements.

Mechanical couplers are also commercially available in stainless steel and other high strength corrosion resistant specialty steels. Manufacturers should be consulted for orders requiring specialty steel or coatings. As with any mechanical splice, test data should be utilized to determine suitability of available products.

When mechanically splicing epoxy-coated or galvanized bars, is it necessary to remove the coating in the bar region being spliced?

Each proprietary system available on the market is different. Some systems are more affected by a coating of epoxy or zinc than others. It is best to contact the manufacturer for information on mechanical splices suitable for applications utilizing coated reinforcing bars.

All damaged coating on epoxy- or zinc-coated reinforcing bars must be repaired. Damaged epoxy coating must be repaired with patching material conforming to ASTM A775 or A934 [2007b] and performed in accordance with the patching material manufacturer’s written instructions. Damaged zinc coating must be repaired with a zinc-rich formulation in accordance with ASTM A780 [2009c]. The maximum amount of repaired damaged coating areas must not exceed 2 percent of the surface area in each linear foot of the bar (ASTM A767, Section X1.3.6).
How can one determine if a mechanical splice and its raw material are domestically produced to satisfy “Buy American” and “Buy America” clauses pertaining to DOT work and other domestic projects?

Perhaps a clarification on these two clauses is appropriate, as the splice manufacturers often field inquiries into the difference between “Buy American” and “Buy America”.

The “Buy American Act” was passed in 1933 by Congress and signed by President Hoover on his last full day in office. The Act requires the U.S. government to prefer U.S.-made products in its purchases, unless the head of the agency involved in the procurement has determined that the price of the domestic supplies are “unreasonable” or the purchase would be “inconsistent with the public interest.” A product is defined as U.S.-made if at least 50 percent of its constituent parts and/or material originated in the United States.

The “Buy America Act” was a provision of the Surface Transportation Assistance Act of 1982 and applies only to mass transit related procurements valued over $100,000, and funded at least in part by Federal grants. This Act requires that Federal-aid funds may not be obligated for a project unless the product is manufactured in the U.S., including all its constituent parts.

Material certifications will indicate the source of the raw materials used in the production of the coupler or coupling sleeve, which manufacturers will provide upon request or when mandated. To avoid problems with certifications, it is best to let the mechanical splice manufacturer know about any specific domestic content requirements before placing an order for mechanical splices.

Are there mechanical splices on the market when the need arises to connect reinforcing bars of different sizes? i.e. #11 to #8.

At times it can be necessary to transition from a larger diameter bar to one that is smaller within a structure. For this application a transition splice can be used and can range from one step transitions to multiple step transitions depending on the design. When joining bars of two different sizes the smaller of the two will govern the performance of the splice much the same as it will in the structure.

Governing Design Codes and Standards

What sections of the ACI 318 Code address mechanical splices?

The ACI 318 Building Code [2011] governs the design of mechanical splices. Specifically, they are referenced in the following sections of the Code:

12.14.3 General requirements
12.15.6 Splices in tension tie members
12.17 Mechanical splices in columns
21.1.6 Mechanical splices in special moment frames and special structural walls
21.8.2(b) Mechanical splices in special moment frames constructed using precast concrete
21.9.2.3(d) Mechanical splices in special structural walls and coupling beams
21.11.7.4 Mechanical splices in structural diaphragms and trusses
21.13.4.1 Mechanical splices in members not designated as part of the seismic-force-resisting system

What is the definition of a Type 1 and a Type 2 mechanical splice?

A Type 1 mechanical splice, as defined in Section 12.14.3.2 of the ACI 318 Code, is a full mechanical splice that develops in tension or compression, as required, at least 1.25 $f_y$ of the bar, where $f_y$ is the specified yield strength of the reinforcing bar.

A Type 2 mechanical splice, as defined in Section 21.1.6.1(b) of the ACI 318 Code, is a mechanical splice that meets the requirements of a Type 1 mechanical splice and also develops the specified tensile strength of the reinforcing bar.

See Table 1 for ACI 318 Code compliant performance requirements for Type 1 and Type 2 mechanical splices for ASTM A615 [2012] and ASTM A706 [2009a] reinforcing bars.

How does the Code define when to use a Type 1 or a Type 2 mechanical splice?

As required in the ACI 318 Code, Section 21.1.6.2, for earthquake-resistant structures:

“Type 1 mechanical splices shall not be used within a distance equal to twice the member depth from the column or beam face for special moment frames or from sections where yielding of the reinforcement is likely to occur as a result of inelastic lateral displacements. Type 2 mechanical splices shall be permitted to be used at any location.”

As explained in Section R21.1.6 of the ACI 318 Commentary:

“The requirements for Type 2 mechanical splices are intended to avoid a splice failure when the reinforcement is subjected to expected stress levels in yield-
Table 1 — ACI 318 Code and IBC compliant performance requirements for Type 1 and Type 2 mechanical splices

<table>
<thead>
<tr>
<th>ASTM Reinforcing Bar Type and Grade</th>
<th>Specified Yield Strength, $f_y$ (ksi)</th>
<th>Specified Tensile Strength, $f_u$ (ksi)</th>
<th>Type 1 ($1.25 f_y$) (ksi)</th>
<th>Type 2 ($1.0 f_u$) (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A615, Grade 60</td>
<td>60</td>
<td>90</td>
<td>75</td>
<td>90</td>
</tr>
<tr>
<td>A615, Grade 75</td>
<td>75</td>
<td>100</td>
<td>93.75</td>
<td>100</td>
</tr>
<tr>
<td>A615, Grade 80</td>
<td>80</td>
<td>105</td>
<td>100</td>
<td>105</td>
</tr>
<tr>
<td>A706, Grade 60</td>
<td>60</td>
<td>80</td>
<td>75</td>
<td>80</td>
</tr>
<tr>
<td>A706, Grade 80</td>
<td>80</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

$f_u$ = specified tensile strength of the bar, per AC133.

How do the Codes vary in their use of mechanical splices?

Chapter 19 of the International Building Code (IBC) is formatted to parallel the ACI 318 Code. The IBC does not contain any amendments to the ACI 318 Code regarding mechanical splice requirements, so the requirements of the two Codes are identical.

How does the performance of a mechanical splice compare to the performance of a lap splice?

All commercially available Type 1 and Type 2 mechanical splice products outperform a lap splice connection in terms of stress transfer. A Type 1 mechanical splice is capable of transferring a stress of 1.25 $f_y$, while a Type 2 mechanical splice is capable of transferring a stress of 1.25 $f_y$ and the specified tensile strength of the bar, but a lap splice is only able to transfer a stress equal to $f_y$ of the steel. For a Grade 60 reinforcing bar with a minimum yield strength of 60,000 psi and a minimum tensile strength of 90,000 psi, a Type 1 mechanical splice can transfer a stress of at least 15 ksi more than a lap splice, while a Type 2 mechanical splice can transfer a stress of at least 30 ksi more than a lap splice. Unlike lap splices, mechanical splices do not depend on the surrounding concrete to transfer load, making them the generally preferred option for designs that anticipate loads greater than the bar yield strength.

Is there an ASTM standard that covers mechanical splices?

ASTM A1034, Standard Test Methods for Testing Mechanical Splices For Steel Reinforcing Bars, covers the methods for testing mechanical splices under the following conditions:

- **Monotonic Tensile Test** – Used to measure the performance of a mechanical splice under an increasing tensile load. The load is increased until failure is reached.

- **Monotonic Compression Test** – Used to ascertain the performance of a mechanical splice under an increasing compressive load. The load is increased until failure is reached or a specified load is applied.

- **Cyclic Load Test** – Used to ascertain how a mechanical splice performs when subjected to alternating tension and compression loads for a given number of cycles. Each cycle may exceed the specified yield strain of the reinforcing bar and is intended to simulate an earthquake loading.

- **High-Cyclic Fatigue Test** – Similar to a cyclic load test, but with the test load staying below the yield strength of the bar. The test is conducted until failure or a specified number of cycles are reached. The test is meant to simulate a mechanical splice in a bridge or other structure subjected to frequent elastic load cycles.

- **Slip Test** – Used to ascertain the plastic movement (slip) between the reinforcing bars within the mechanical splice, when loaded in tension.

- **Low-Temperature Test** – Used to test the suitability of a mechanical splice for use in a structure expected to operate at extremely low temperatures.

- **Combination Tests** – More than one of the tests described in ASTM A1034 is conducted concurrently.

It is important to note that ASTM A1034 describes only the methods used for testing mechanical splices, and does not quantify any testing parameters or accep-
Detailing and Placement of Mechanical Splices

Is the mechanical splice considered part of the bar when satisfying Code prescribed concrete cover requirements?

A mechanical splice is considered part of the bar when satisfying concrete cover requirements. Therefore, the bars being “spliced” may have a greater general concrete cover as the splice region governs the minimum requirements.

Does the ACI 318 Code restrict either the length or the diameter of mechanical splices?

ACI 318 places no restrictions on the dimensions of a mechanical splice. When accommodating mechanical splices in design and construction, it is helpful to have some idea of the overall dimensions for a typical splice, but as seen in Fig. 7 dimensions vary due to the numerous types of splices available. It is important to verify proper coupler or coupling sleeve dimensions prior to detailing in order to have accurate information for checking clear spacing and cover requirements.

Does the Code require mechanical splices to be staggered?

Generally ACI 318 does not require a Type 1 or Type 2 mechanical splice to be staggered. There are only three specific cases where staggering of mechanical splices is mentioned in the Code:

1. Section 12.15.5.1 requires a 24 inch minimum stagger for the so-called “Type 0” (zero) mechanical splice, which does not meet the requirements of a Type 1 or Type 2 mechanical splice and is limited to bar sizes #5 and smaller.

2. Section 12.15.6 requires Type 1 mechanical splices be staggered at least 30 inches for tension tie members. A tension tie member has the following characteristics: a member having an axial tensile force sufficient to create tension over the cross section; a level of stress in the reinforcement such that every bar must be fully effective; and limited concrete cover on all sides. Examples of a tension tie member are arch ties and the main tension elements in a truss.

3. Section 12.17.3 requires a mechanical splice used in a column to be at minimum a Type 1 mechanical splice. Commentary R12.17.3 states that mechanical splices in columns are permitted, but should be designed as full Type 1 mechanical splices in order to reflect the high compression loads possible in column reinforcement due to creep effects. If a mechanical splice developing less than a full Type 1
mechanical splice is used then the splice is required to conform to all requirements of end bearing splices for staggering.

What is the basic reason for staggering mechanical splices?

Staggering mechanical splices is done for a variety of reasons and is at the option of the designer. Two primary reasons are:

1. **Constructability** - Under some circumstances, where bar centers are very close, staggering might help to provide adequate room for installation of the mechanical splices.

2. **Satisfy Spacing and Cover Requirements** - Under some circumstances, where bar centers are very close, staggering might help facilitate meeting the spacing requirements of Section 7.6.3 of the ACI 318 Code. This section requires the clear spacing between longitudinal bars be at least 1.5 in. and 150% of the bar diameter $d_b$. In the case of bars that are mechanically spliced, the clear spacing requirement is typically applied to the spacing between neighboring splices, although this section does not specifically address clearance limits for mechanical splice couplers.

In the December 2011 *Concrete International* "Detailing Corner" [CRSI Staff 2011], CRSI provided some additional information regarding the staggering of splices. The ACI Committee 439 [2007] Report, "Types of Mechanical Splices for Reinforcing Bars" has some good information regarding splice staggering.

When using mechanical splices in typical segmental concrete pours, it is impractical to stagger. How does the ACI 318 Code address this typical application where staggering is not practical?

For applications where it is impractical to stagger mechanical splices, depending on the design, a Type 1 or Type 2 mechanical splice should be used. The ACI 318 Code does not require these types of splices to be staggered, unless there is a tension-tie condition, so all mechanical splices located at one section of the member are acceptable. Figure 8 shows an arrangement of mechanical splices without any stagger.

**Figure 8 — Non-staggered mechanical splices.**

Is a mechanical splice considered part of the bar when satisfying Code prescribed bar to bar spacing requirements?

A mechanical splice is considered part of the bar when satisfying bar spacing requirements. This is similar to the concrete cover requirements.

After they are installed, can mechanical splices touch one another? Are there any provisions in the ACI 318 Code that would not allow mechanical splices to touch one another, as would be the case in bundled bars where mechanical splices are used to connect the reinforcing bars?

Concrete spacing requirements are dictated by the building code. All required spacing must be maintained per the prescribed code and design practice. In the case of bundled bars, the bars are permitted to touch. Because mechanical splices are considered to be part of the bar, then in this situation, the mechanical splices would be permitted to touch.

**Qualification of Mechanical Splices**

What Evaluation Service organizations evaluate mechanical splices to the IBC?

Currently there are two evaluating service (ES) organizations that evaluate mechanical splices to the International Building Code (IBC). One is the ICC Evaluation Service (ICC-ES), a nonprofit, limited liability company, which is a separate, stand-alone subsidiary of the International Code Council (ICC). The other organization is the International Association of Plumbing and Mechanical Officials (IAPMO), Uniform ES. Both evaluation services are accredited to the same standards and provide equivalent independent review for compliance to the building codes.

The ICC-ES has its own acceptance criteria (AC) for mechanical splices, which is Acceptance Criteria for Mechanical Connector System for Steel Reinforcing Bars (AC133) [ICC 2010]. IAPMO also evaluates to this criteria.

Once a mechanical splice is out of its original packaging, is there any way to determine the necessary conforming product information? For example, what reinforcing bar sizes is this coupler intended for and what is the performance objective of this coupler, i.e. Type 1/Type 2?

Most manufacturers of mechanical splices provide this information by stamping on the outside of each coupler. In AC133, Section 2.1.2, second paragraph requires each component of a mechanical splice be identified to indicate whether the connector is a Type 1 or Type 2 mechanical
splice. Often times only the higher of the two performance requirements, Type 2, is stamped as a Type 2 mechanical coupler always meets the requirements of a Type 1. Contact the manufacturer for specific identification details as they can vary.

Are there any documents that contain information on the different mechanical splices that are commercially available today?

There are presently two documents:

1. **Reinforcing Bars: Anchorages and Splices** by CRSI [2006]. The CRSI document presents the following information on mechanical splices:
   - Provides common terminology
   - Lists various types of mechanical splices manufactured by CRSI member companies
   - Lists the testing results of mechanical splices
   - Provides tables of minimum strength requirements for mechanical splices
   - Describes mechanical splices for coated reinforcing bars (epoxy or zinc)

2. **Types of Mechanical Splices for Reinforcing Bars - ACI 439.3R-07** [2007]. The ACI document contains the following information on mechanical splices:
   - Provides definitions
   - Lists various types of mechanical splices
   - Summarizes the common usage of mechanical splices
   - Lists the design requirements and considerations of mechanical splices

**References**

- American Concrete Institute - ACI Committee 116 (2005). *Cement and Concrete Terminology* (ACI 116R-00, Reapproved 2005), American Concrete Institute, Farmington Hills, Michigan, 73 pp.
- American Concrete Institute - ACI Committee 318 (2011). *Building Code Requirements for Structural Concrete (ACI 318-11) and Commentary (ACI 318R-11)*, American Concrete Institute, Farmington Hills, Michigan, 503 pp.
- American Concrete Institute - ACI Committee 349 (2006). *Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary (ACI 349-06)*, American Concrete Institute, Farmington Hills, Michigan, 153 pp.
- American Concrete Institute - ACI Committee 439 (2007). *Types of Mechanical Splices for Reinforcing Bars (ACI 439.3R-07)*, American Concrete Institute, Farmington Hills, Michigan, 20 pp.

**Contributors:** Michael Ugalde, Lou Colarusso, Robbie Hall, Sean Hirka

**Keywords:** Buy America, Buy American, couplers, coupling sleeve, mechanical splices, stagger, Type 1, Type 2


**Historical:** None. New Technical Note.

**Note:** This publication is intended for the use of professionals competent to evaluate the significance and limitations of its contents and who will accept responsibility for the application of the material it contains. The Concrete Reinforcing Steel Institute reports the foregoing material as a matter of information and, therefore, disclaims any and all responsibility for application of the stated principles or for the accuracy of the sources other than material developed by the Institute.