Mechanical Rebar Splicing Systems for Cast-in-place Concrete Structures

Used properly, mechanical connections can increase structural integrity as well as jobsite productivity and safety

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Before rebar can be used in a typical reinforced-concrete structure, designers and contractors must carefully plan how to join long lengths of reinforcing steel. Although lap splicing is the most common method, it is not always the most practical, economical, or desirable. When designers and contractors are concerned about issues such as congestion, convenience, structural integrity, and load transfer, it is often worthwhile for them to consider using mechanical connections .

TENSION-COMPRESSION SPLICING SYSTEMS

Because jobsite conditions vary tremendously, manufacturers provide a wide variety of mechanical connections. Of these many mechanical splicing systems, tension-compression devices are perhaps the most versatile. Unlike either tension-only or compression-only splicing devices, tension-compression systems can transfer both compressive and tensile forces along the length of the rebar—giving designers and contractors more flexibility when they choose a splicing system.

Some of these systems, however, are designed to meet special needs and can be more practical in one situation than another. To choose the best tension-compression device for standard cast-in-place structures, designers and builders must evaluate each system's technical capabilities as well as its installation requirements. The use of epoxy-coated rebar may also greatly affect a splice decision.

Tension-compression systems can generally be placed in either of the following categories:

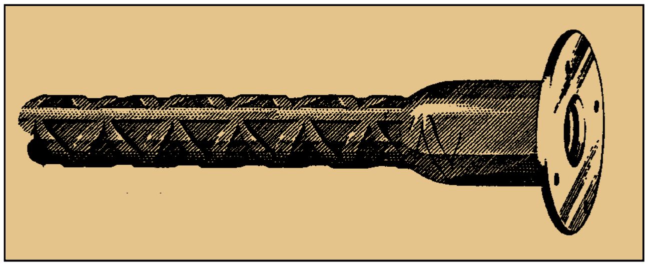
- Systems that act as dowel bar substitutes
- Systems that use couplers to join lengths of rebar

Dowel bar substitutes splice rebar across construction joints; some systems connect bars that are generally sized smaller than or equal to #6, while others accommodate #4 to #11 rebar. Couplers generally join rebar sized from #3 to #18, and can also join rebar of different diameters.

Couplers can be threaded or nonthreaded. Threaded couplers are generally screwed onto the end of a length of rebar and tightened; then the second bar is torqued into place. Couplers with no internal threads cannot be torqued. Instead, they are positioned over the butted rebar ends, then locked into place. As for dowel bar substitutes, the male-threaded bar is screwed into the exposed end of a concrete-encased coupler. As the following examples of some typical systems illustrate, there are many different ways to achieve all of these connections.

DOWEL BAR SUBSTITUTES

Using dowel bars to create struc-



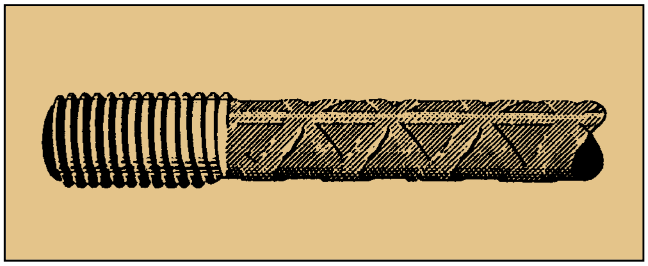


Figure 1. **A typical two-piece splicing system: This dowel bar splicing system consists of a male-threaded bar (right) and a female-threaded, one-piece, integrally forged coupler component (left) manufactured from rebar material.**

tural continuity across construction joints usually results in one or more of the following problems:

- Drilling of the formwork, which prevents reuse of the forms
- Rebar protruding from the formwork, which can be a safety hazard
- Bending and rebending of the rebar, which can weaken the bars

To eliminate these problems, several manufacturers developed dowel bar substitutes (also known as dowel bar replacements) to take the place of a one-piece dowel bar.

There are three common types of dowel bar substitutes, depending on the type of thread the system utilizes. The first type is a parallel-threaded system, also referred to as a straight- or normal-threaded system. In this system, the thread is cut into the bar ends. The second type of dowel bar substitute is an upset-threaded system. The man-ufacturer of this system upsets (enlarges) the bar end before rolling the straight threads so the parent bar's cross-sectional area is not reduced. The third type is a taper-threaded system.

Installation. These products are either two-piece (Figure 1) or three-piece (Figure 2) systems. A two-piece system features a coupler that is integrally forged to the bar length, while a three-piece system features a coupler that connects two lengths of rebar. Fastening either type's coupler component to the form face generally requires nails, wood screws, or threaded bolts.

The coupler component is encased in the first concrete placement, along with the first bar, which was either attached or integrally forged. After the formwork is stripped, the second bar is threaded into the exposed end of the coupler (Figure 3) to complete the connection across the joint. Threaded systems should be tightened with a pipe wrench to eliminate thread movement and resultant concrete cracking.

Bar preparation. No special bar-end preparation is required, but protective plugs and caps must be used. These plugs and caps prevent concrete from entering the coupler and fouling the threads. Dowel bar replacements are generally either straight, hooked, or headed. Manufacturers provide users with a choice of 90-degree hook bars, 180-degree hook bars, or headed upset bar ends. Straight bars can be threaded at one end or at both ends.

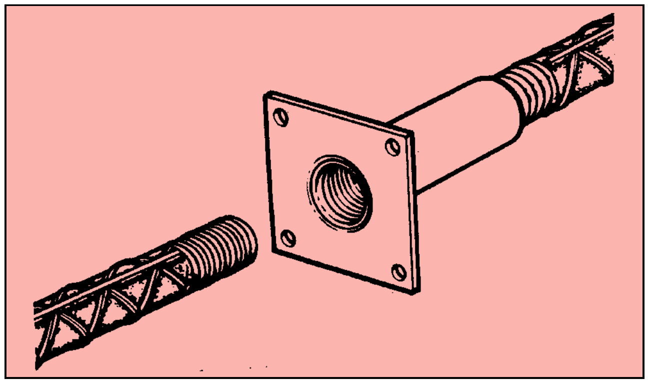


Figure 2. **A typical three-piece splicing system: Two externally threaded bar lengths are joined by an internally threaded coupler.**

THREADED CONNECTIONS

Taper-threaded Couplers

One of the most common types of mechanical connections, this system consists of a taper-threaded coupler (Figure 4) that butt-splices two lengths of rebar, each threaded to match the coupler.

Installation. Users initially screw the coupler onto one bar end. The mating bar is placed in the coupler and rotated approximately four turns by hand. The connection is finished by using a pipe wrench to tighten the connection. An inspection wrench may be used periodically to ensure that connections are sufficiently tight to prevent movement during concrete placement.

Bar preparation. Taper-threaded couplers require the use of taper-threaded rebar. Standard Grade 60 rebar is used and can be threaded in the fabricator's shop or on-site with a portable bar threader. Contractors must also make sure—before splicing the rebar—that the threads of the coupler and the bars

Reasons for Using Mechanical Connections

Although lap splicing is certainly the most common way to splice rebar, using mechanical connections can increase productivity, safety, and structural integrity. Engineers and contractors should consider using mechanical connections if they want to:

- Increase structural integrity in seismic zones
- Increase structural integrity in load reversals
- Maintain a consistent steel-to-concrete ratio
- Transfer loads independent of the concrete, allowing the rebar to react essentially as a continuous piece of unspliced rebar
- Reduce congestion
- Reduce crane time
- Eliminate the drilling of formwork
- Eliminate protruding rebar

Contractors should also remember that engineers are sometimes required to consider mechanical connections. For example, to splice #14 and #18 rebar in tension-compression applications, the bars must be either mechanically connected or butt-welded.

Figure 3. **To secure a construction-joint connection, workers must insert the mating bar into the exposed end of the coupler. Encased in the concrete is the coupler, as well as the bar that was previously attached to the coupler.**

are clean and undamaged. Bar protectors can lessen the likelihood of thread damage.

Straight-threaded Couplers with Upset Rebar Ends

Suitable for joining #6 through #18 bar, this system consists of a straight-threaded coupler that butt-splices two lengths of rebar, each threaded to match the coupler. The system's manufacturer, however, upsets the bar ends prior to rolling the threads so the parent bar's cross-sectional area will not be reduced by the threading process.

Installation. Users must screw the coupler onto the threaded splice bar. After butting the other threaded bar and reversing the thread, the splice is complete. One manufacturer can also provide an electric or pneumatic tool with a wide torque range to speed installation of the couplers.

Bar preparation. Since the manufacturer provides the threaded bars, no preparation is necessary; however, it is important to keep the threads clean and undamaged.

Couplers for Thread-deformed Bars

Users of this system can place couplers anywhere along the length of reinforcing steel because the entire bar is threaded. Each bar—supplied by the manufacturer in sizes #6 to #20—features hot-rolled threads along the length of the bar.

Installation. The installation of this system calls for slightly different accessories, depending on the desired application—compression only, tension only, or tension-compression. (The coupler is used alone for compression-only splices, with lock nuts for tension-only splices, and with hex nuts for full tension-compression splices.) For tension-compression splices, when opposing threadbars are not torqued together, the coupler is engaged on the bar ends and a torque wrench is used to tighten a hex nut against each end of the coupler.

Bar preparation. No special bar-end preparation is required for tension-compression applications of this system.

SWAGED CONNECTIONS

Cold-swaged Couplers

Well suited for jobs using large bars, these couplers are swaged—deformed onto reinforcing bars —using a press fitted with a removable, two-piece die set (Figure 5).

A swaged coupler can be one-piece, two-piece, or three-piece. The one-piece coupler is a seamless steel tube that is swaged to the butted ends of the rebar lengths. In contrast, a two-piece coupler is threaded, and it consists of a female-threaded coupler and a matching male-threaded coupler. Users of this system rotate the bars to engage the threads. A three-piece threaded coupler can be used when neither bar can be rotated. It consists of two threaded female ends and an interconnecting steel stud with a right-hand thread on one end and a left-hand thread on the other.

Installation. Swaging couplers in the field requires a portable, hydraulic press. (To swage in the shop, fabricators use a larger, bench-type press with adjustable stops and insertion probes.) The press fits around the coupler and bar and hydraulically pushes the inner die toward the outer die to deform a segment of the coupler onto the bar. Some presses can be activated with a control button, but a foot switch is generally used. This

Figure 4. **This system's taper-threaded coupler is used to butt splice two lengths of rebar, each threaded to match the coupler. The mating bars (not shown here) will be placed in the couplers, rotated by hand, and tightened with a pipe wrench.**

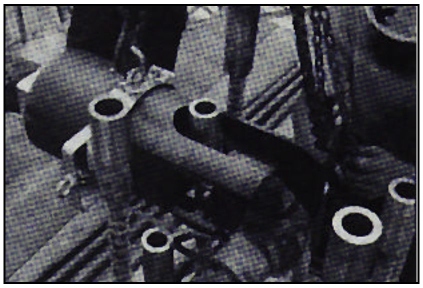


Figure 5. **Users of a cold-swaged system must crimp the couplers onto the reinforcing bars using a hydraulic press fitted with a removable, two-piece die set. This deformation process will be repeated along the length of the steel coupler.**

deformation process is repeated along the length of the coupler.

Installing the threaded systems is a two-stage process. After the unthreaded section of each coupler is cold-pressed onto the rebar, the two bars are joined by either rotating one of the two bars, or by turning the threaded steel stud and drawing the bars together with a turnbuckle effect.

Bar preparation. Neither the nonthreaded nor the threaded cold-swaged coupler system requires special preparation of the bar ends.

METAL-FILLED CONNECTIONS

Metal-filled Couplers

One of the most tested mechanical connections, metal-filled couplers (Figure 6) are filled with molten steel to connect rebar that range in size from #5 to #18. This type of system is often used for bridges, nuclear containment vessels, and other special-purpose structures, including those that must resist live loads, wind loads, or loads generated by blasts or earthquakes.

Installation. After the coupler has been centered over the bar ends, a pouring basin and crucible are attached to the coupler. The powdered metal material is placed in the crucible and ignited, so that molten metal flows into the coupler, where it interlocks the coupler's grooves with the bars' deformations. Both vertical and horizontal splices can be made with this type of system.

Bar preparation. Although no special bar-end preparation is required, it is important to remove any concrete or loose rust.

OTHER SYSTEMS

Set-screw Couplers

Consisting of a steel tube with a series of lockshear bolts—generally six to eight—and two serrated strips that run the inside length of the coupler, this splicing system (Figure 7) can be especially useful on projects where bars are in place or access is limited.

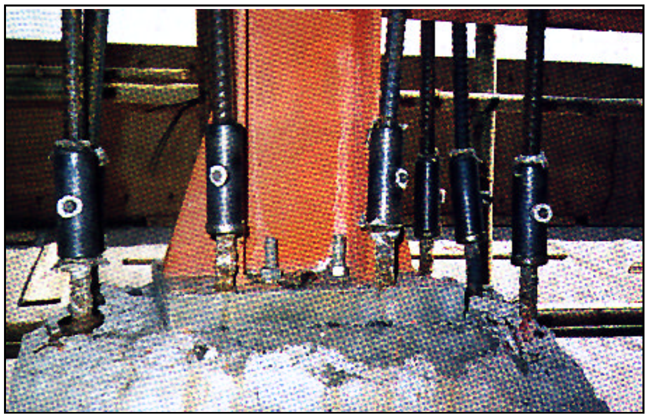


Figure 6. **One of the oldest mechanical connections, these metal-filled couplers have been filled with molten steel. Users of this system must place powdered metal material in a crucible, ignite it, and allow the molten metal to interlock the couplers' grooves and the bars' deformations.**

Installation. After sliding one length of rebar halfway into the coupler, the bolts are tightened to fit snugly. The second bar is then inserted into the coupler until it butts against the other bar end, and the remaining bolts are tightened to a snug fit. A ratchet or an impact wrench is used to tighten the bolts until their heads shear off, implanting the bolt ends into the rebar and embedding the serrated strips into both the rebar and the interior coupler wall.

Bar preparation. This type of splicing system does not require special bar-end preparation.

At this time, a number of new mechanical splicing systems are being developed and some established systems are being used in different ways. These developments accompany a growing awareness of the benefits of mechanical connections, especially in seismic areas. ACI Committee 439, ICBO Evaluation Service, and CALTRANS have all been testing the performance of commercially available mechanical connectors. The goal of ACI 439, for example, is to classify mechanical connectors' ability to fully connect and develop reinforcing bars under severe inelastic strains. The premise: Given the right performance data and testing services, engineers and con-

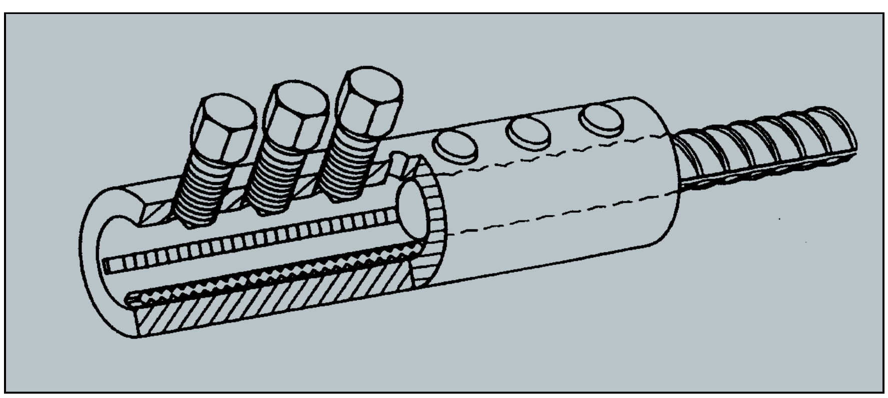


Figure 7. **This system is not threaded, swaged, or metal-filled: It features a steel tube with two serrated strips and a series of lockshear bolts. A ratchet or a wrench implants the bolt ends into the rebar and embeds the serrated strips into the coupler wall and the rebar.**

tractors can choose a mechanical connector that will perform exceptionally well—even under the most rigorous conditions.

References

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