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Overview of reinforcing steel mechanical joints

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Abstract
Mechanical bar splices are an engineering method used to connect reinforcing bars, which are widely used in bridge construction, foundation projects, high-rise buildings and other fields. Compared with traditional connection methods such as welding and lap splicing, mechanical bar splices have better load-bearing capacity, quality stability, high efficiency, safety performance and economy.
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Ⅰ. INTRODUCTION

The transmission mechanism of mechanical connection joints for steel reinforcement mainly involves the following aspects:
1) Mechanical locking: The two bars are tightly locked together by the connectors to make them a whole. In the force, the connection member through friction and embedded force to achieve the transfer of force between the reinforcement. As in the case of threaded connections, the connecting member is a threaded sleeve, and the threads of the two bars and the sleeve threads engage each other to form a solid connection.
2) Bond force transfer: Some grout sleeve mechanical joints, using grout material to fill the gap between the sleeve and the reinforcement. Under load, the force between the two reinforcing bars connected is transmitted through the bond between the reinforcing bars and the grout material and the bond between them, the friction and the friction between the grout material and the sleeve together.
3) embedded transfer of forces: Some types of reinforcing steel mechanical connection joints, such as cold compression joints, produce local plastic deformation of the contact surface between the connection and the reinforcing steel ribs by cold extrusion of the connection. When the load is applied, the transfer of force is achieved by the embedded force between the connection and the reinforcement.
The following are some of the most common mechanical connection joints:

1.1 Threaded bar splices

Figure 1.1 shows a sample of a threaded sleeve mechanical joint with a reinforcing bar end that is threaded and engages with the internal threads of the connecting joint to complete the splice. The threads can be of different orientations and lengths. For example, in Figure 1.1(a), the threads are parallel, however, as shown in Figure 1.1(b), the tapered threaded joint has non-parallel threads and the diameter of the rebar decreases from the end of the joint toward the middle of the joint. Due to thread failure, the strain capacity of the tapered threaded connection is significantly lower than that of the rebar (ultimate strain less than 0.05)[1] , while the straight threaded connection has similar stresses and strains as the reference rebar (ultimate strain over 0.1)[2] . In some products, the ends of the bars are forged to larger diameters, thus avoiding that the ends of the bars can become weak links after turning the wire.

（a） Straight thread (b) Tapered thread
Figure 1.1 Threaded sleeve mechanical joint

1.2 Head bar splices

Figure 1.2 shows a sample of a head-type mechanical coupling, which consists of a male component with a thread and a female component with a matching female thread, with the splice completed by corresponding threaded tooth fit. Each half of the coupler is forged on the corresponding rebar, and the ends of the rebar are forged into a

T-shape. Ultimate stresses and strains were adequately achieved in static, cyclic and dynamic tests, but the strain capacity at the joint was adversely affected as the strain rate increased (over 0.1 in the slow test and less than 0.07 in the fast test)[2,3] .

Figure 1.2 Header type mechanical joint

1.3 Shear screw bar splices

Figure 1.3 shows a sample of a shear screw mechanical joint using screws to hold the rebar extruded to a steel sleeve. Premature failure of the reinforcement led to a significant reduction in the strain capacity of the connection using this joint, although the ultimate strength of the reinforcement reached 90% of the ultimate strain of the reinforcement, with an ultimate strain of less than 0.04[4] . The damage occurred at the end of the connection for the connection using three screw anchors, while for the connection with four screw anchors, the damage occurred at the reinforcement outside the connection area, and the extension of the length of the connection resulted in a threefold increase in strain capacity[5] .

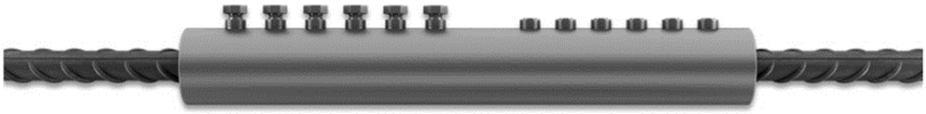


Figure 1.3 Shear screw mechanical joint

1.4 Extruded sleeve mechanical joints (Swaged bar splices)

Figure 1.4 shows a sample of an extruded sleeve mechanical joint. The fastener consists of a seamless steel sleeve that is cold pressed against the reinforcement to provide the embedding force. The ultimate load of the reinforcement using the extruded sleeve fastener was comparable to that of the whole bar, and large ultimate strains (over 0.08) were observed in the test[1] .

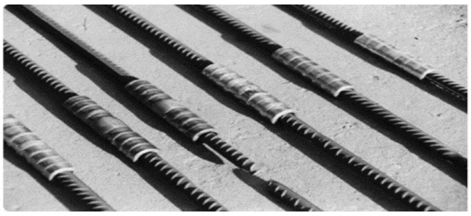
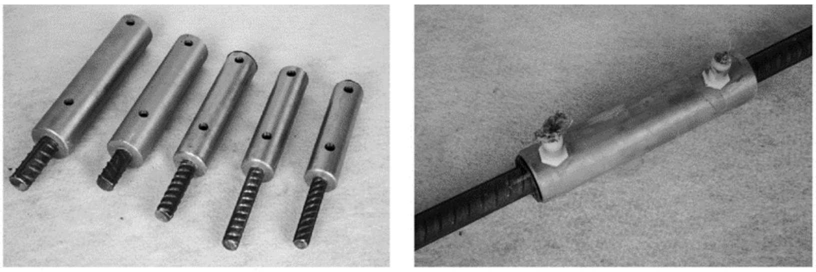


Figure 1.4 Extruded sleeve mechanical joint

1.5 Grouted Sleeve mechanical joints(Grouted Sleeve bar splices)

Figure 1.5 shows a sample of a grouted sleeve mechanical joint, consisting of two parts, grout and sleeve, where the reinforcement and the joint are connected by grout adhesion. The specimens of the semi-grouted sleeve connection were tested in tension, the mortar fragmentation phenomenon appeared in the necking stage and caused the end mortar blocks to fall off due to the obvious vibration at the moment the reinforcement was pulled off, the loading rate basically did not affect the bearing capacity of the semi-grouted sleeve specimens because the sleeve and the reinforcement at the other end were made as a whole and the deformation of the steel consumed part of the energy generated by the dynamic load . The load capacity of the fully grouted sleeve connection specimens as a whole tends to increase with the increase of loading rate, and the load capacity of the specimens under dynamic testing is higher than that of the specimens under static testing.



(a)semi-grouted sleeve (b)Full grouting sleeve

Figure 1.5 Grouting sleeve mechanical joint

1.6 Hybrid bar splices

Connections that use both of these anchoring mechanisms are classified as hybrid mechanical joints. Figure 1.6 shows a sample of a hybrid mechanical joint with a threaded grouted mechanical joint: the joint has a threaded end and a grouted sleeve at the other end.

Figure 1.6 Hybrid mechanical joint

Table 1.1 Summary of mechanical joints

Mechanical joint type	Force transmission mechanism	Applicable buildings	Advantages and disadvantages
Threaded sleeve mechanical joint	By screwing the reinforcement into the matching threaded connector with a torque wrench and stopping when the design torque is reached, the load between the connected reinforcement is transferred by the teeth of the connector and the threads on the reinforcement.	Suitable for new construction or rehabilitation of reinforced concrete structures.	Advantages: easy to operate, high processing efficiency, can be made in advance, no electricity is required for installation, continuous construction is possible without affecting the schedule, and the threaded joint is one of the smallest connections. Disadvantages: high processing requirements for the wire buckle on the end of the reinforcement, rust protection, straightness requirements, and higher cost than welded joints.
Head type mechanical joint	The head components transfer the load between the bars by matching the threaded teeth with each other.	Suitable for new construction or rehabilitation of reinforced concrete structures.	Advantages; the head joint is usually the smallest joint produced, as the head member does not need to be long to adequately transfer the load.
Shear screw mechanical joint	A screw is used along the length of the connection to press the reinforcement against the sleeve on the other side, which connects the reinforcement to the connection by friction and transfers the load between the reinforcement.	These connectors are typically used in new construction due to their large size. However, in an experimental study, such connectors were used to replace broken longitudinal steel bars in bridge piers.	Advantages; No treatment of the rebar ends is required and can be installed quickly with simple tools. Disadvantages; special screws are required to hold the rebar in place. The connection is usually large and requires several screws to fully squeeze the rebar, which can result in higher stresses at the squeeze.
Extruded sleeve mechanical joint	The end of each bar is slid into the sleeve, half of each, and then the sleeve is compressed by a hydraulic jack. When the sleeve is compressed, the ribs of the ribbed reinforcement slightly deform the inside of the sleeve to form an anchorage.	Similar to shear screw connectors, they are often used in new construction due to their larger size and to replace broken longitudinal reinforcement in bridge piers.	The connections are relatively large because sufficient length is required to anchor the reinforcement. This length provides good stress distribution throughout the rebar, with no load concentrated at one point. No handling of the reinforcement is required in the field, but special equipment is needed to secure the sleeve to the reinforcement.
Grouting sleeve mechanical joint	The connection is made by filling the sleeve with mortar, and after the mortar sets, the load is transferred between the steel sleeve and the	Grouted sleeve connectors are typically used to connect prefabricated elements in prefabricated structures.	No handling of the ends of the bars is required and they are the fastest to install in the field. These connections are the most common connections because of their ease of installation and high structural tolerances.

	reinforcement by the mortar adhesion.		
Hybrid mechanical joint	Both of these force transfer mechanisms are available.	Suitable for new construction or rehabilitation of reinforced concrete structures.	Has the advantages and disadvantages of any two of the above connections.

Different forms of rebar connection are suitable for different construction scenarios. By optimizing the rebar connection method, different construction processes can be extended. For prefabricated piers, the difference in construction mainly depends on what kind of mechanical joint is selected for the rebar.

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