TECHNICAL NOTE 10

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Steel Reinforcement Institute of Australia

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Mechanical Splices

General

Mechanical couplers are a means to splice reinforcing bars in tension or compression, without the need for lapped splicing of the bars. They can be used to reduce reinforcement congestion and improve structural integrity as they do not rely on the concrete to transfer the stress from one bar to the other. They also improve constructability, allow prefabrication of larger steel reinforcement cages, allow splicing of tension-tie members, connections to previously cast elements, and also assist in repair or retrofit work by allowing connection onto existing reinforcing bars.

In general, the performance requirements for mechanically splicing Ductility Class N bars are covered in Clause 13.2.6 of both AS 3600 and AS 5100.5, or are provided by the state transportation authorities. Generally, if the mechanical splice is providing a full-strength connection (bar-break failure away from the coupler zone) and the longitudinal slip in the connection is less than 0.1 mm, then the mechanical splice is deemed to satisfy the performance requirements. In case the longitudinal slip in the connection is more than 0.1 mm, then the Consulting Engineer should consider the potential detrimental effects of excessive slip during the design process. In addition to this, depending on the project requirements, performance of the mechanical splices under high cycle fatigue loading needs to be reviewed as well. Also, Clause 13.2.1(e) of AS 3600 states that they are the only option for splicing bars larger than 40 mm. They are also specifically referred to in Clause 10.7.5.3 of AS 3600 as a means for splicing column reinforcement.

Specific detailing requirements for end-bearing splices in columns are also covered in Clause 10.7.5.4 of AS 3600: the splice must always be in compression, additional fitments are required above and below the splice and most importantly, the ends of bars are to be held in concentric contact by a clamp.

While end-bearing splices, formed by providing a sleeve around the bar ends to ensure that they remain in contact, are mentioned in Clause 10.7.5.4 of AS 3600, they are typically no longer used and as such, are not covered in this Technical Note. However, they are still found in many historic reinforced concrete structures and when assessing these structures, their locations should be identified and taken into account when determining the capacity of the structure, as they cannot transfer any tensile loads.

While there are many different suppliers of mechanical couplers in the marketplace, they fall into two basic types: threaded couplers (**Figure 1)** and coupling sleeves (**Figure 2**).

Threaded Couplers

Threaded couplers come in a variety of arrangements, including parallel threads and tapered threads and sleeves swagged over the bar ends with the individual sleeves then screwed together. A variation on this is friction welded couplers, where the rotation of the coupler against the bar end (with lateral force applied) generates sufficient localised heat from the friction to weld the bar end to the coupler **Figure 3**. The bars can then simply be screwed together on site as usual. This avoids the need for threading of the bar end or swagging the coupler over the end of the bar.

For specific proprietary bar types, threaded couplers have also been developed to suit the proprietary 'thread type' rib pattern rolled onto the surface of these bars (**Figure 4**), again, avoiding the need to thread the end of the bar, or swage a coupler onto the bar.

Variations of threaded couplers have been developed to allow connection where both bars cannot be rotated (eg bars cast into precast elements), and where a gap between bars needs to be bridged.

Coupling Sleeves

Coupling sleeves come in two basic types: mechanically bolted or grouted **Figure 2**. They are ideal where bars are embedded in concrete and threading of the ends or swaging couplers onto the ends are not options. This makes them ideal for repairs and retrofit works. Mechanically bolted couplers rely on the clamping of the bar against a serrated edge for load transfer, and coupling sleeves rely on the injection of a high-strength grout around the bar to anchor the bar end within the coupling sleeve.

Apart from the standard remedial and retrofit works, grouted coupling sleeves can also be used for precast connections as it allows for more adjustability in the connection than standard threaded couplers or bolted coupling sleeve connections. They reduce the installation time in the precast factories and enable connections in much thinner elements.

Parallel Thread

Tapered Thread

Sleeve swagged over bar end with parallel thread

Figure 1 Types of threaded couplers

Mechanically bolted

Grouted

Figure 2 Types of coupling sleeves

Figure 3 Friction welded threaded coupler

Figure 4 Proprietary bar couplers

Headed Reinforcement

Another extension of mechanical couplers is headed reinforcement, which essentially involves fixing a steel disc (or head) onto the end of the bar. The steel head can either be screwed directly onto the threaded end of the bar (**Figure 5**), screwed onto a threaded coupler swagged onto the end of the bar (**Figure 6**), or a mechanically bolted headed connection can be used **Figure 7**. Similar to hooks and cogs at the end of the bar, headed anchors are used to develop the bar over short distances where the required embedment to develop the bar is not available, or the incorporation of cogged ends on bars to facilitate development is not practical. Note that provided the minimum requirements of Clause 13.1.4(i) to (iv) of AS 3600 are satisfied, then the headed end of the bar will account for at least 50% of the development length in tension, $L_{sy.t}$.

Headed reinforcing bars are covered in Clause 13.1.4 of AS 3600, which requires the net bearing area of the head to be at least four times the cross-sectional area of the bar being anchored. The actual size of the head must be allowed for, and a check made to ensure that it can be incorporated into the element and cover is maintained. The clear cover for the bar shall not be less than $2d_b$ and the clear spacing between bars shall not be less than $4d_b$. Also, the bar diameter (d_b) shall not exceed 40 mm. It is important to note that Clause 13.1.4 of AS 3600 states that where the tensile force in a headed bar could give rise to bearing forces directed towards, or adjacent to, a free concrete surface, failure of the concrete cone between the head of the bar and the free concrete surface shall be investigated. Regarding this aspect, Clause 25.4.4 of American Concrete Institute Standard ACI 318M-19 provides further guidance.

With the requirement in Clause 13.1.2.6 of AS 3600 for bars having a yield stress greater than 400 MPa, to provide a transverse bar in contact with the corner of a bar having a cog or hook for anchorage, and for the transverse bar to extend at least 4 times the bar diameter ($4d_b$) of the bar being anchored on either side of the hook or cog, the use of headed reinforcement to anchor bars may be one of the only options.

When detailing cogs or hooks for anchorage of bars, the requirement to provide the corner bar should be allowed for and a check made to ensure that the $4d_b$ extension of the bar past the cog or hook can be incorporated into the concrete element, without compromising the required cover for durability.

Figure 5 Headed mechanical anchor screwed onto threaded bar end. The thread can either be tapered (as shown) or parallel (refer Figure 1)

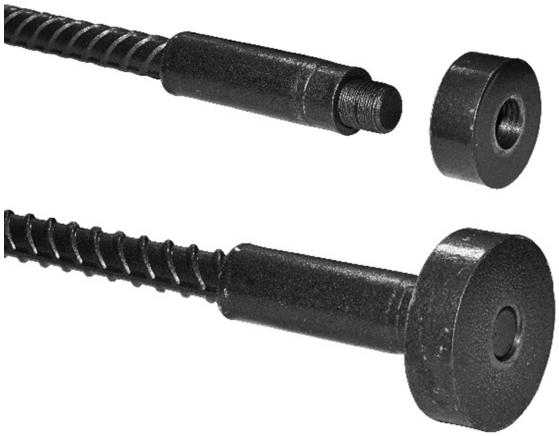

Figure 6 Headed mechanical anchor screwed onto swagged coupler

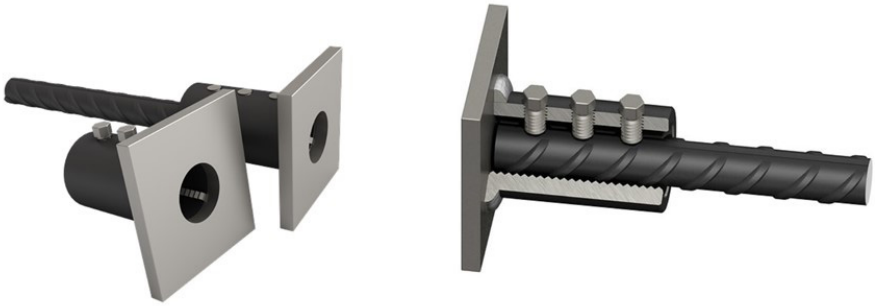

Figure 7 Mechanically bolted headed reinforcement

Detailing of Mechanical Splices

When detailing mechanical splices:

- Consult the manufacturer's websites or product brochures to determine how to specify the particular type of threaded coupler or coupling sleeve required for the application. Contractors may request a substitute product depending on the supplier of the reinforcement (because different processors work with different systems), therefore the performance requirement for a mechanical splice must be specified on the drawings or in the specifications.
- When selecting a particular mechanical splice, ensure that the manufacturers documentation states that the system complies with Australian or other equivalent International Standards. As couplers are part of an Australian Standards compliant reinforcement solution, if non-conforming couplers are used then the steel reinforcement solution will no longer meet the engineering design requirements.
- Ensure that the required cover is obtained to the mechanical coupler. This may require detailing additional cover to the reinforcing bars to allow for the thickness of the mechanical coupler. Note that in Australian Standards there is no reduction in the cover when hot dipped galvanised couplers (or reinforcement) are used.
- Where mechanical splices are located in areas such as construction joints and joints between precast walls, and where moisture occurs and durability is of concern, then consideration should be given to the use of a protective coating such as galvanising to both the mechanical couplers and bars. The longitudinal slip in the connection should also be considered, particularly if more than 0.1 mm or when durability requirements require crack widths less than 0.3 mm.
- When detailing the number of bars within the reinforced concrete elements, consider whether the spacing allows the incorporation of the mechanical couplers. If the minimum clear spacing between couplers cannot be provided (Clause 4.14.2 of AS 5100.5 requires 1.5 times the maximum nominal size of the aggregate or the diameter of the reinforcing bar), consider detailing the coupler locations to be staggered, or using fewer, slightly larger bars to increase the spacing between bars. Also, in determining an appropriate clear spacing, the ability to adequately place and compact the concrete must be considered, and this may require spacings larger than the minimum. Factors that may affect the spacing include the size and shape of the member, placement method and workability of the concrete.

- For bundled bars, it is essential to stagger the location of mechanical splices in order to maintain the location of bars within the bundle.
- For coupling sleeves, where grouting is used as a mechanism to lock the system in place, the high strength grout injected within the sleeve also needs to be specified and should be in accordance with the manufacturer's requirements.
- For headed reinforcement, ensure the size of the circular, square or rectangular head can be accommodated within the section and the required cover can be achieved.

Further information

The SRIA website (sria.com.au) has links to a number of Associate Members that supply a range of mechanical splice solutions:

- Dextra
- DWIDAG
- Leviat (Ancon)
- nVent (LENTON)
- Reid Construction Systems
- SILVA (Dextra splices)
- SRG Global