Mechanical Splicing Couplers for Reinforcement

Mechanical Splice/Join is the common terminology for the complete assembly including the coupler or sleeve fitted to provide a splice of two reinforcement bars. Mechanical couplers are relatively, a new concept in India. We have been working with mechanical couplers for almost 17 years now, but like any new concept, it takes a few years to be accepted and incorporated as a practice in the Construction Industry. In the initial years, even though couplers were accepted as a technically superior product, it was very difficult to convince the owner/contractor to opt for couplers due to factors such as low steel cost and the mindset to prefer conventional technique of lap joint as a safer option. Increase in the pricing of rebar (Almost three fold in the past 12 years), approval of consultants in the concept of couplers, increasing international exposure to Indian Engineers, pace and complexity of construction have all contributed in the acceptance of mechanical splicing for various projects.

There are various types of mechanical splices but in this
In this article, we will restrict ourselves to the threaded couplers which are the most common types of couplers in use.

**Need of Using Couplers:**

Using Mechanical Splice offers various advantages over the conventional method of overlapping of reinforcement bars. Some of the prime reasons are as follows.

- **Spliced rebar performs like continuous reinforcement due to mechanical joint, unlike lapping which has complete dependency on concrete.** This eliminates errors due to providing wrong lap length. Reduction of concrete grade, compaction or segregation issues with concrete, concrete deterioration over time or due to sudden impact which causes reduction in lap joint strength.
- **Steel Wastage is reduced significantly.** Using couplers saves lap length steel. While lapping can only be carried out in lap zones, it is possible to use couplers outside of lap zones. This also provides the added advantage of using standardized lengths. A 12m rebar can be divided into 3m or 4m as bars as required which also prevents the wastage of end pieces of steel which are not used in lapping.
- **Couplers can be used as a replacement to dowel bars which also saves formwork material.**
- **Steel congestion is reduced due to elimination of laps.** This also aids in proper flow of concrete in the critical zones and hence improves the quality of the overall structure.
- **Non-threaded coupler options can be used for extensions of steel in location as an alternative to welding.**
- **Using couplers provides superior cyclic performance as compared to lap joint.** It also allows greater flexibility for the designer.
- **It is possible to easily verify joint strength in case of Couplers as compared to lap splices where the testing is cumbersome and not regulated.**
- **For the contractor, usage of couplers reduces labour cost for installation and handling of steel. The construction schedule is improved and there is saving on valuable crane time on the project.**

**Different Types of Coupler Systems:**

The choice of the mechanical coupler system for the project depends on various factors. Selection of the most suited coupler system should be made after considering all advantages and limitations of the coupler system, the project parameters, location of coupler joint and the preferences of the structural consultant for the project.

Broadly, Mechanical couplers can be classified in the following two main categories – threaded and non-threaded couplers.

**Threaded couplers** are sub-categorized into taper and parallel threaded couplers. The cross-section and length of the coupler is determined by the grade of rebar for which it is designed. The general coupler systems are described below but one should note that certain modifications are possible in each system as per manufacturer and application requirements.

**Taper Threaded Couplers:**

A mechanical splicing system with tapered threaded couplers is one where the threading carried out on the rebar is at a slight incline. The slope of the threading and the coupler is kept the same to ensure engagement of all threads simultaneously in the coupler joint.

Tapered couplers are generally longer in length as compared to parallel couplers and number of threads is generally mentioned as a range. There is a tolerance allowance in tapered couplers for length of threading to be carried out on rebar. Tapered threaded couplers are designed taking into account defects of the rebar such as undersizing, skewness and oblongness of the rebar.

Tapered threaded couplers are the simplest type of
threaded couplers where the threads are cut out on the rebar at an angle. These type of couplers are suitable for columns in general and can be used in horizontal applications but it is necessary to ensure tightening of the joint. These couplers require that the rebar be turned for tightening and hence it is difficult to use such couplers in rafts or other applications where it is not possible to turn the rebar and tighten the same.

**Roll Threaded Couplers**

Roll Threaded couplers are a type of parallel threaded couplers where threads are formed by pressing the ends of the rebar using a set of rollers and are then connected by a coupler with matching parallel threads. The rebar end need to be cut perpendicular prior to threading as there is no allowance for additional threads inside the coupler in parallel threaded systems.

Roll Threaded couplers are suitable for both horizontal and vertical application. Due to parallel threads, in columns, more turns are required for tightening the coupler and hence installation takes more time as compared to tapered system. Roll Threaded couplers provide an option of position threading – where one side of the joint can be threaded to the coupler length and the coupler can be turned to tighten the joint in location instead of rotating the rebar. However suitability of this application is to be determined based on the rebar available, as there will be a reduction in joint strength for this specific application. For vertical applications, full strength joint is achieved.

The machine for Roll Threaded splicing is more portable and such systems can be recommended for projects with coupler requirements in both raft/beams and columns. In such a system, it becomes necessary to ensure proper threading. Gauges are to be provided to ensure tolerance limits for threading on site. There can be situations where the splicing may have a play if the bars provided are undersized. In such case, it may become necessary to consider alternatives.

**Cold Forged Couplers/Upset Parallel Threaded Couplers**

Cold Forged Or Upset Parallel threaded couplers are formed by enlarging the rebar end by 10-30% under hydraulic pressure prior to cutting parallel threads on to the up-sized rebar.

Cold Forged couplers are suitable for both horizontal and vertical application. Due to parallel threads, in columns, more turns are required for tightening the coupler and hence installation takes more time as compared to tapered system. Cold Forged couplers also provide an option of position threading. Due to forging of the rebar, there is no reduction in the joint strength even while using the position coupler option.

Precautions which are needed for cold forged couplers include ensuring that there is no play between the threads formed in this process and the coupler. Gauges are used to ensure tolerance of the threads in such cases. It is vital that the rebars used in this process have sufficient ductility or else there is a risk of micro-cracks being formed during the forging process. In such cases, the joint strength may be severely affected.

**Non-Threaded Couplers:**

There are various sub-types of non-threaded couplers which are used mainly for installation of couplers in location where it is not possible to use threaded couplers or for specialized applications. This category includes but is not limited to crimple/swage couplers, welded couplers, Bolted couplers, couplers with injected sleeves, friction-weld couplers. They are also required to conform to the same standards as the threaded couplers unless specifically approved by the consultant.
The Non-threaded couplers are mainly used as repair aids and are not used extensively in new construction due to their higher costing, bulky couplers and slower installation procedure.

**Code Specifications:**

In India, the structural consultant is free to define the code to which the couplers used for the project are required to conform to. While there are a number of different codes around the world for coupler manufacture and joint threading, some of the most common and relevant ones are listed below with a brief summary of their requirements.

1. **American Concrete Institute (ACI) BUILDING CODE 318, 2008**

   The ACI 318 -2008 code is the most commonly referenced code for mechanical couplers. It is purely a performance based code and categorizes splicing into two groups – Type 1 and Type 2. A Type 1 joint is required to achieve 1.25Fy as a minimum while Type 2 is required to comply with 1.25Fy requirement and also meet the specified tensile strength of the rebar.

   The ACI code accepts steel which has a specified minimum tensile strength. For example, for Fe500, while Fy=500 N/mm², the ultimate stress expected from the same is at least 700 N/mm². In view of this, the code can be read as such. For Type 1, the joint is expected to have a tensile strength not less than 1.25Fy=625 N/mm² while for Type 2, acceptance is at 700N/mm².

   In India, steel acceptance is determined by IS 1786 which is a code inspired from the British standards. Fe500 is considered acceptable for use anywhere in the structure if it meets ultimate strength of 545 N/mm² which is much lesser than the 1.25Fy requirement of the ACI code. In India, the Type 2 condition becomes at least 625N/mm² as well.

   Let us interpret the code as per its actual purpose. Type 1 was a reduction allowance from the ultimate tensile stress of the rebar for the joint; however, the code also restricted the location of its use, mainly in the zones where the stress on the member would be significantly lesser i.e lap zones. If the joint could sustain the ultimate design requirement, it could be used freely anywhere in the structure. In our case, if the steel meets 625N/mm² criteria, it is much greater than the acceptance criteria of 545 N/mm² as per IS 1786. In the current market, along with main steel, lot of projects are also approaching rolling mills to procure re-rolled rebars which may have consistency issues. They do meet minimum acceptance criteria as per IS 1786 but sometimes do fall short of the ACI requirement of 625N/mm² and in such cases applicability of the ACI 318 code is questionable. In such cases, it is usually up to the structural consultant to decide if acceptance criteria should be as per ACI 318 or as per IS 1786. It has been observed that for manufacturers which provide steel complying with the ACI requirements, the joint has been able to meet 700N/mm².

2. **IS:SP:34 (S&T) – 1987 Section 4**

   This code specifies various types of mechanical splices and provides recommendations for usage of splicing systems and strength requirements. Acceptance of the results has been left to the structural consultant. Compliance is usually verified against IS 1786 steel code.

3. **BS 8110-Part 1, Section 3, 1989**

   While the British code has lower acceptance criteria as compared to the ACI code, it specifies tensile testing and Slip Test for the joint for acceptance of the sample.

4. **BS 5400: Part 4: 1990**

   The BS 5400 is a code for design of concrete bridges and details requirements for lapping bars, welding, providing sleeve and for taper and parallel threading of rebar. Staggering of the rebars has been recommended along with usage of such connections in lower stress zones. Tests include tensile stress, slip test and fatigue tests.

5. **ASME CC – 4330, 2004, Section III, Div 2:**

   The ASME Code provides a list of different types of splices and their acceptance criteria. The tests which are
required to be carried out include tensile tests and cyclic tests. Acceptance in tensile test is defined as being no less than 90% of the actual tensile strength of the reinforcement bar being tested and not less than the minimum specified strength. The individual splices also have to conform to the 125% of the specified minimum yield strength requirements. This condition for a rebar complying with ACI 318 requirements would mean that the joint is expected to have at least \(0.9 \times 700 = 630\text{N/mm}^2\) which is not less than its specified minimum of \(625\text{N/mm}^2\).

The cyclic test prescribed is for 100 cycles of stress variation from 5% to 90% of the specified minimum yield stress. The tests are meant for design confirmation of the coupler and are required to be repeated if the coupler parameters such as size, material, cross-section area are changed or if the coupler is redesigned for higher grade of rebar.

6. IS 16172:2014 Reinforcement Couplers for Mechanical Splices of Bars in Concrete- Specification

The IS 16172:2014 is a manufacturers code for production of couplers only and is not meant for site execution. It is recommended that the coupler be designed for Fe550 grade as a standard. The performance of the mechanical splice is to be determined with reference to IS 1786:2008 and IS 456:2000. The drawback of this classification is that even if the coupler is designed for a higher grade of rebar and has sufficient capacity, the cyclic and tensile tests will not reflect the site conditions.

The only tests recommended for acceptance on projects as per this code are static tensile tests which are considered as per IS 1786:2008 code. So for example, while a Fe500 rebar breaking at a stress of \(580\text{N/mm}^2\) would be rejected as per the ACI coldal criteria of \(625\text{N/mm}^2\), the same sample would be considered acceptable as per the IS 1786 requirement of \(545\text{N/mm}^2\). This will facilitate the use of relatively sub-standard rebar for preparation of joints effectively reducing the factor of safety for the joint. In such a case, it is up to the site and consultant to ensure that such a practice is not promoted.

Concerns

As we had mentioned earlier, couplers gained acceptance in the Indian construction industry after the steep increase in steel reinforcement prices. However, one has to remember that the Mechanical splice consists of the Coupler as well as the rebar which is spliced to form the connection. Rebar parameters do affect the coupler performance. Some of the parameters which affect the coupler joint are as follows:

- **Grade of the Rebar:** While most suppliers claim that there is a consistency in the reinforcement steel being supplied to the project, there are variations in the grade of the rebar, especially in case of re-rolled rebar. If there is an error in the chemical constitution of the rebar or if there is a presence of cavities in the steel, it is possible for the rebar to exhibit variations such as reduction in joint strength, issues with bending/ re-bending of steel and cracking of the rebar during threading/ upsetting operations.

- **Ductility:** It is generally believed that the higher the ductility of the rebar, the better the bar for execution. While the IS 1786 code prescribes a minimum ductility, there is no upper limit for the same. A very high ductile rebar can cause issues such as faster necking of the joint during tensile test in plastic zone and slippage of threads leading to early breakage. The ductile versions are better suited to operations of cutting and bending but do not help in mechanical splicing.

- **Size and shape of rebar:** Sometimes the rebar provided is not circular in shape or is skewed in appearance. In such cases, the threading appearing on the rebar may seem uneven. Care has to be taken to account for such variations during the design of the coupler.

- **Rib Size:** The cross-section of a rebar is measured theoretically by weighing the standard length and then calculating the apparent area of the rebar. If the ribs are excessive, it means that the core circumference of the rebar would be smaller as compared to another rebar with smaller rib and having the same weight. This is same as
under sizing of the rebar for threading and can lead to play in the coupler joint and/or lower ultimate strength. 

Along with the rebar, care has to be taken regarding the coupler material and specifications. Couplers are generally designed to meet one grade higher specifications than the rebar they are meant for. The coupler materials physical and chemical properties also determine joint strength and are to be monitored carefully as well.

Another concern is to ensure a set of workers who are skilled in operation of these threading machines to ensure that the joints are prepared within the approved tolerances and group of fitters who are used to installation of the splice on the project. Initial training and supervision is necessary to ensure a hassle free installation.

Looking Forward:

The Indian construction industry is progressing rapidly, with existing mega-cities expanding vertically due to the constraints on horizontal expansion and with upcoming new cities all over the country. Mechanical couplers, even though a relatively new system, has proved to be technically superior to conventional techniques, helping to increase the pace of execution and the quality of projects. It also saves steel which is now a valuable national resource and is also cost-effective in comparison to lap joints.

Couplers have already been incorporated in the construction industry. It is necessary to ensure that proper checks are maintained on this product to ensure compliance with structural strength and ductility requirements.

Author’s Bio

Uday Sheth, Director, Ishita Enterprises holds a Civil Engineering Degree (B.Tech) from IIT-Mumbai (1980 Batch) and has practiced as a formwork designer and consultant and is also a contractor specialized in retrofitting of structures. He has been actively involved in introduction, promotion and execution of mechanical coupler systems on various projects since 1998. He has an experience of 35 years in the construction industry.

Dhruva Sheth, Director, Ishita Enterprises holds a Masters Degree in Construction Engineering and Management from Civil Engineering Department, Texas A&M University (2007 batch) and is actively involved in the execution of couplers on various projects in India for over seven years.

Ishita Enterprises is one of the pioneer firms in India and currently offers all types of threaded coupler options along with crimp/swage couplers.

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MECHANICAL SPLICING SYSTEM

Researchers from the UAB Department of Chemical Engineering have devised an unique method to derive electrical energy and hydrogen by using a wastewater treatment process. The proposed system uses bacteria which consumes organic material and produces electric current.

Currently, there are treatments in which wastewater can flow out to the river or sea without causing any environmental problems. These technologies however entail high energy costs, mainly in aeration and pumping, and an elevated economic cost in treating the sludge left over from the treatment process.

Wastewater contains an elevated amount of chemical energy in the form of organic contaminants. In order to make use of this energy, researchers from around the world study ways to recover it in the form of hydrogen, a process which efficiently eliminates organic matter from wastewater. It not only reduces the amount of energy needed during the process, it also obtains energy from the produced hydrogen. The key to achieve this is what is known as microbial electrolysis cells (MEC). What is needed is a very special type of bacteria, exoelectrogenic bacteria, capable of oxidising organic material and generating electricity which in turn produces hydrogen. These cells only need a bit of added voltage, much less than what is used for water electrolysis, and which is recovered with the hydrogen, thereby generating clean energy.

Researchers from the Bioelectrochemistry group of the UAB Department of Chemical Engineering have achieved to improve the energetic efficiency of the cells. The experimental results were very positive and demonstrated that these systems would have a market niche at industrial scale. The scientists, coordinated by professors Albert Guisasola and Juan Antonio Baiza, used real wastewater instead of the biodegradable synthetic water used in most experiments, and achieved a biological production of hydrogen and, to a large extent, the recovery of a good part of the energy contained in the residues. To achieve this, researchers selected a set of bacteria capable of transforming complex substrates such as methanol, dairy waste, starch and glycerol, into simpler compounds which could, in turn, be degraded by exoelectrogens.

The results were very positive and high hydrogen production and energy intensity was obtained through the wastewater treatment. In the long term, the MEC fed with dairy wastewater yielded the best results in terms of current intensity (150 amps per cubic metre of reactor), in hydrogen production (0.94 cubic metres of hydrogen per cubic metre of reactor and day), and in recovery of electrons at the cathode (91%), all that with an applied voltage of only 0.8V. These results are the basis for a potential industrial development of this technology and therefore for the creation of systems capable of producing hydrogen from wastewater treatment.

Renewable energy obtained from wastewater