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CRITICAL REVIEW ON MECHANICAL SPLICING SYSTEM FOR REINFORCEMENT STEEL

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Abstract: The reinforced concrete is widely used in civil engineering industry globally. Construction of reinforced concrete (RC) structures are mainly required the use of concrete and reinforcement steel (rebar) to resist compression and tension respectively. Rebars are limited to Stock length and this limitation make it impossible to provide full length continuous bars in most RC structures. Therefor splicing of rebars become essential and which is done by various methods like lap splicing, weld splicing and mechanical splicing. Lap splicing has become the traditional method of connecting the rebars. Mechanical splices are commonly used to connecting two steel reinforcing bars when rebars of larger diameter used in heavy congested RC structures. This paper represented the method of splicing and critical review of past work carried out on Mechanical splices. A reviewed literature also shows the effectiveness of mechanical splices over conventional splices like lap splice.

Keywords: Splices, Lap splices, Mechanical splices, Reinforcement coupler, Reinforcement concrete, Beam.

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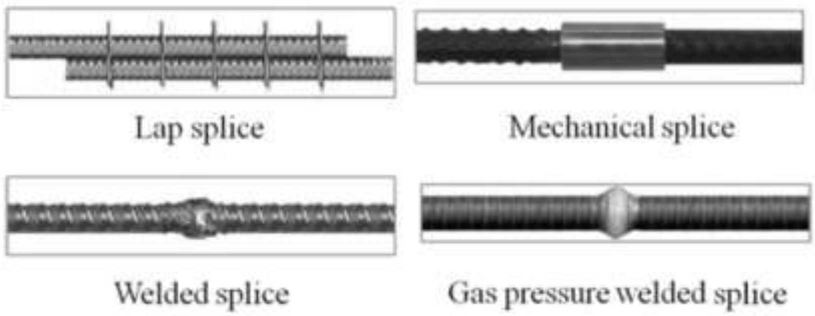
INTRODUCTION

Length of the reinforcing bar is limited by fabricating, transporting or storage capacity and normally supplied in standard stock length up to 12 m – 18 m. As a result, the length of steel bars could not ensure the integrity of throughout any sizeable structures. Therefore, splicing reinforcing bars is unavoidable. Basically, there are four kinds of splice included lap splice, mechanical splice, welded splice and gas pressure welding splice (Figure 1).



Figur 1 Splice of reinfocing bars

Among these four kinds of splice, mechanical splice is used popularly in construction of RC structures. For using mechanical splices, the principal is that mechanical splices should not decrease the load bearing capacity, ductility and stiffness of the structures compared to the structures without splices. It means that using mechanical splices does not create weak points affecting the performance of the structures. Mechanical splices are now produced satisfying the requirements on load carrying capacity, ductility and stiffness of the reinforced concrete members. However, during the installation process, mechanical splices may not achieve the quality as expected. The properties of such mechanical splices and their effect on behavior of reinforced concrete members have been hardly clarified. There are numerous studies about mechanical splices focusing on mechanical properties of mechanical splices, developing new mechanical splices or effect of mechanical splices on the behavior of the structures.

Lap splicing has become the traditional method of connecting two steel reinforcing bars. Lap splice and welded splices have various imperfections such as poor quality of welds, increased labour cost, requires skilled labour inadequate length of laps, failure at joints, etc. In the reinforced concrete structures, some reinforcing bars must be spliced. The length of bars required may be longer than the stock length of steel. Splicing with lapped joints is not an appropriate means of connecting reinforcing bars always. The use of lapping requires more steel in terms of design and installation. Lapped joints are not that effective mean of splicing since it has various disadvantages such as greater congestion, time consuming and also lap splices are not considered reliable under cyclic loading and they are not effective for larger spans and have many “hidden” costs and it does not provide load path continuity, independent of the condition of concrete[12].

Mechanical splices i.e. the coupler system is used to connect two bars in field quickly and easily. Hence mechanical splices such as threaded couplers can be very effective since they ease the design parameters, easy in installation and also reduce the amount of reinforcement required. Hence more and more engineers are specifying mechanical reinforcement connections overlap splices since they have found that mechanical connections afford a reliability and consistency that can't be found with lap splicing. Mechanical splices deliver higher performance than a typical lap splice. Generally, this is approx. 125% - 150% of the reinforcement bar and this is also economic means of connecting two bars[12].

Mechanical couplers are used for connecting HYSD bars. Generally, couplers are manufactured from mild steel, but in some cases alloys of different metals can also be used. Like EN8D material is used for making couplers having high carbon contents and high strength. The material should be such that couplers meet the minimum strength requirement (125% of yield strength of rebar). A very important aspect of coupler selection is selection of material and specification. Every manufacturer gives his own specifications regarding coupler selection.[12].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 [11]. As per IS-16172:2014 (Annex-A Pg. no.4) Different Mechanical Splicing Systems based on: Threaded Coupler and Coupling Sleeve. Threaded Couplers: Tapered Threaded, Parallel Threaded & Upset Parallel Threaded Couplers [10].
Laboratory Based Testing Setup

The specimen beam is kept in horizontal direction as shown in Figure 2. Both ends of the RCC beams are fixed by using strong built up steel boxes which in turn are connected to the reaction floor using holding down anchor bolts. To facilitate the application of monolithic load on the RCC beam, hydraulic jack of 25 Ton capacityis used which are connected to the strong steel frame using mechanical fasteners and the RCC beam was loaded as shown in Figure 2. The Linear Variable Differential Transducer (LVDT) was connected on either side of the specimen to monitor the displacements. To record the loads accurately, the specimen was tested to reach its maximum failure load.

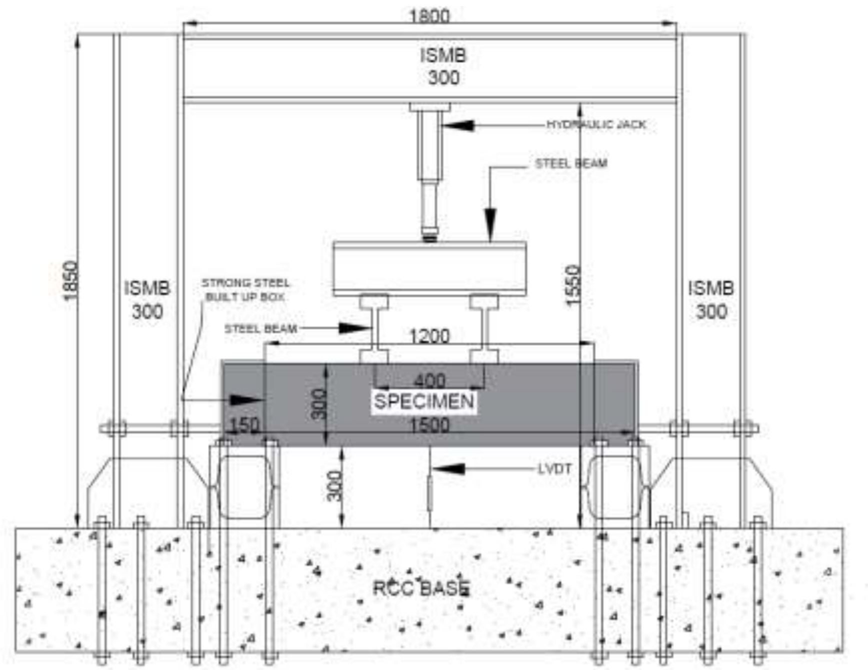


Figure 2 Schematic diagram of test setup

REVIEW OF LITERATURE

Steven L. McCabe (2000)[1]This paper shows the results of the largest independent study of mechanical splices which was conductedat the University of Kansas, UnitedStates and is specially aimed at the performance issue. In response to a question raised by the ACI Building Code Seismic Subcommittee as to the viability of the present design requirements for splices subjected to seismic loading.Three separate types of tests were conducted to evaluate the behavior of the mechanical splices: (1) Monotonic Tension Test, (2) Stepped Cyclic Test& (3) Uniform Cyclic Test. The results of this testing program have shown that not all splice will produce performance like mechanical splices, which are indeed capable of effectively connecting reinforcing bars together and that many are capable of producing bar breakage as the failure mode. As present in the ACI 318-99 Building Code there are two levels of splice performance that are permitted – non-seismic and seismic levels, which are difference the strength and ductility. The results of this study, A consistent performance definition and testing protocol for mechanical splices that will allow the designer’s vision to be upheld in these important connection regions is within our grasp.

Vidmantas Jokūbaitis & Linas Juknevičius (2010)[2]Many sources present various characteristics of thereinforcement couplers and test results proving their reliableperformance under the both static and dynamic loading. As per researcher’s reinforcement bar spliced by threaded couplers can be treated as a solidone without any splice.Generally, there are very few research results concerning the behavior of reinforced concrete members with reinforcement couplers, neither published in the scientific journals nor otherwise available in any other sources. In this paper the appearance of normal crack development at the end of the coupler is investigated by the Cracking analysis of beams with tensile reinforcement spliced by Threaded reinforcement couplers of Lento system.12 experimental RC beams(the class *BSt*500 rebar of 12 mm dia. with couplers and without with reinforcement coupler splices) were made for analysis of their performance under the short-term loading.4 beams (MS series) with reinforcement couplers,4 beams (DS series) with couplers and 4 beams (S series) without any couplers. Only 2 of 8 couplers spliced test beams failed in the cracked c/s at the end of the coupler when the threads of the splice were cut.

Singh R., Himanshu S. K. & Bhalla N. (2013)[3]This is a case study of an under-construction site where “tapered thread couplers” were used in the columns only in place of lap splices. Only 14 columns were considered for this study, which was carried out at Jaypee Greens incipient undergoing project 'Wish Town Klassic' elongated over 40 acres in sector-129 of Noida, India.The majority of couplers used were for 25mm and 20mm diameter bars. Couplers for 16mm diameter bars were used only up to 3rd floor. Total Number of couplers used was 1182. Cost comparisons done between Coupler splice and Lap splice (by Site & IS-code methods). Which is show only economical aspect of mechanical splice.

Kıvanc Taşkın & Kerem Peker (2015)[4]This study will present the results of independent study of mechanical reinforcement splices conducted at the Anadolu University of splicing systems marketed in Turkey. The purpose of this research was to provide recommendations for use of mechanical connection systems in both static and seismic conditions. Assessment of the international literature reporting on mechanical connection testing protocols and experimental studies conducted in the United States, Japan, and Europe, which provide recommendations for Turkish reinforced concrete standard for Both static and seismic conditions, in terms of their relevance in the Turkish context. Two separate types of tests were conducted to evaluate the behavior of the mechanical splices: (1) Monotonic Tension Test & (2) Stepped Cyclic Test.New criteria can be used on mechanical connection systems in both static and seismic conditions and must proposed for the Turkish code. Two criteria were proposed for use of mechanical connection systems in seismic conditions, being strength and serviceability limit state. Preliminary tests indicated that mechanical connection systems commonly used in Turkey met the proposed criteria.

Nguyen Dac Phuong & Hiroshi Mutsuyoshi (2015)[5]The mechanical properties of mechanical splices with insufficient steel bar insertion into the couplers were experimentally investigated along with the influence of such splices on the behavior of RC beams. The effectiveness of a corrective splice newly developed to improve such improperly installed splices was also studied. In this experimental study, first tensile test of six mechanical splices with different bar embedment length was carried out by UTM and after that all 10 RC beams were 3.0 m length with a span of 2.5 m and a squarec/s of 0.30 m. Results of beam tests by load-displacement relationshipand crack width and crack spacing. Now, to investigate corrective splice for improving insufficient embedded mechanical splices, tensile test carried out and after that investigate the four beams with corrective splices. Results of beam tests by load-displacement relationshipand crack width and crack spacing.

Swami P. S., Javheri S. B., Mittapalli D. L. & Kore P. N. (2016)[6]This study presents, tensile load tests carried out for 16 mm, 25 mm & 32 mm dia. HYSD (Fe 500) rebars with lap spliced, welded spliced and mechanical (threaded coupler) spliced specimens by Universal test machine (UTM) and coat analysis also done in this study.

Prof. S. N. Harinkhede & Dr. Valsson Varghese(2017)[7]The study of Mechanical coupler was divided into structural analysis, specifications &manufacturing andeconomical survey between mechanical and lap splices. Their performance was analysed on the basis of ultimate tensile capacity and percentage elongation, which is done by Tensile test on mild steel couplers and EN8D couplers for 20 mm rebars. In this study, mild steel couplers fail in tension test, because the thickness and strength of coupler is less as compared to the EN8D couplers having high strength and thickness. Couplers having high carbon contents have high strength and in addition with greater thickness are more sustainable and effective.

C. Neeladharan, Thouseefur Rahman M., Shajahan A., Himayun Javaad S. & Jibran Saquib K. (2017)[8]The length of the coupler is decided as 3, 5 and 8 times the diameter of the steel rod &the specifications of mechanical couplers are given in table 2.The tests were conducted on 12mm and 16mm Fe-500 steel rods. So, the couplers were made by matching steel rods, which a constituent of the material is within the permissible limit. Couplers are manufactured on a metal lathe machine. The normal lapped splices, welded splices and coupled splices bars are subjected to tension test by using UTM (± 1000 KN). From the different length of couplers (3D, 5D& 8D), where small length of coupler (3D) performed well due to less reduction in main bars. After testing of developed and coupled bars, the length of coupler (L= 3D) gave good result when compared to welded splices and development length (i.e. L_d =45D) as per IS 456:2000.

Table 2 Specification of made coupler

Specimen ID	Dia. of bars (mm)	Length of Coupler (mm)	External Dia. (mm)	Internal Dia. (mm)	Depth of thread (mm)	Pitch (mm)
MC-04	12	36	16	10	2	1.2
MC-05	12	60	16	10	2	1.2
MC-06	12	96	16	10	2	1.2
MC-01	16	48	20	12	2	1.2
MC-02	16	80	20	12	2	1.2
MC-03	16	128	20	12	2	1.2

Summary of Findings

A detailed review of previous research on mechanical splicing system and use of mechanical splices in reinforced concrete beam or column are present in this paper. Based on the previous research on mechanical splicing system following summery are coming out,

- Use of Mechanical splices give continues load path in reinforced concrete and only use for HYSD bars like Fe 500, Fe 550, Fe 550D, etc.
- Mechanical splices provide good strength and ductility to reinforced concrete structure. This splice is reduced steel congestion in RC structures and reduce steel use which give economic benefits.
- Especially threaded one mechanical couplers are used, which globally available and use to use at site.
- Generally, couplers are manufactured from mild steel, but EN8D material-based couplers having high carbon content and high tensile strength which effective then mild steel.
- Mostly, mechanical splices tensile test carried out and economical survey done (16, 20, 25 &32 mm) for column only.
- Smaller length of coupler provides good strength. (like 3d, d = dia. of bar)
- Mechanical spliced failed very early in the cracked cross-section at end of the coupler. But, the cracks at ultimate load not opened like normal splice and very few fail in the cracked c/s at end of couplers.
- ForLocation point of view, Mechanical couples more effective at middle splice of beams over the staggered splices beams.

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