Reinforcement Couplers As An Alternative To Lap Splices: A Case Study

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Abstract

Construction practices in the building of concrete structures have focused on the use of steel reinforcement to transfer tension and shear forces. Lap splicing has become the traditional method of connecting the steel reinforcing bars. Splicing the reinforcement bars by laps or welding have various imperfections such as low quality welds, inadequate length of laps, failure in joints, increase in labour cost etc. Present study was focused on the use and applicability of reinforcement couplers, especially threaded ones as an alternative to lap splices. A case study of an under construction site was taken where couplers were used. An estimation of the cost of couplers was done. Alternatively, the cost of steel was also determined for providing lap splices in the columns. A comparison was done to show the difference of cost in lapping and use of couplers. It was found that the use of reinforcement couplers significantly reduces the consumption of both construction time and reinforcing steel. It also increases the overall reliability of reinforcement splices. This case study included calculations for 14 columns and showed that how couplers have effectively saved a huge amount of money in a single building. The reinforcement couplers not only provide strength to the joints but they are also an economic means of connections of two bars.

Keywords: Reinforcement couplers, Lap Splices, Column, Threading, Joints

Introduction

There are three basic ways to splice the bars: Lap splices, Mechanical connections and Welded splices. Lapped joints are not always an appropriate means of connecting reinforcing bars. The use of laps can be time consuming in terms of design and installation and can lead to greater congestion within the concrete because of the increased amount of rebar used [1]. It also increases the overall reliability of reinforcement splices. Of the three, lap splicing is the most common and usually the least expensive. Couplers especially threaded one can simplify the design and construction of reinforced concrete and reduce the amount of reinforcement required. The coupler system is designed to connect two pieces of rebar together in the field quickly and easily. Taper threaded splices utilize the time-tested, field proven taper thread for assurance of strength, consistency and reliability while simplifying installation. Designed for use with worldwide grades of rebar, they develop the full tension splice strength requirement per numerous design standards [2].

The coupler system is available in several styles to meet virtually any application. The applications include standard bar-to-bar connections, precaging applications, hooked bar applications, closure pours, precast connections, rebar terminations and anchorages, transition splices, segmental construction and connections to structural steel. Most popular splicing systems are Interlock, Quick wedge, Speed sleeve, Terminator, Lock, Form saver, Taper thread splices, and Cad weld splices.

More and more engineers are specifying mechanical reinforcement connections over lap splices. They've found that mechanical connections afford a reliability and consistency that can't be found with lap splicing [3]. Lap splices depend upon concrete for strength so they lack structural integrity and continuity in construction. Mechanical splicing assures the maintaining of the continuity of the Load path in the reinforcement, independent of the condition of concrete. Mechanical splices deliver higher performance than a typical lap splice. Generally, this is 125% -150% of the reinforcement bar [4]. Mechanical splice can bear and can deform more than a lap splice before failure occurs. Lap splicing, which requires the overlapping of two parallel bars, has long been accepted as an effective, economical splicing method. Lap splices usually are in contact, but in flexural members the bars can be separated by as much as 6 inches. Bond between steel and concrete transfers the load in one bar to the concrete and then from the concrete to the other (continuing) rebar.

This transfer of load is influenced by the deformations, or ribs, on the rebar. In projects with small bar sizes such as of number 6 or number 8, relatively low yield stress in steel and building heights of 15 stories or less, lap splices have performed well over the long run [5]. In recent years, however, there has been a shift. Continuing research, more demanding designs in concrete, new materials and the development of hybrid concrete/structural steel designs have forced designers to consider alternatives to lap splicing. Structural concrete building frames are being pushed to 100 stories and more. Current design practice for structural framing uses bar sizes from number 8 to number 11 with yields of 60 or 75 ksi. And concrete strengths of 8000 to 12,000 psi are accepted by code and increasingly used. Use of higher-strength concretes allows for shorter lap lengths. However, these concretes are more susceptible to splitting failures, raising questions about the adequacy and reliability of lap splices.

Material and Methodology

The research work was divided into different headings as structural analysis, manufacturing and specifications, estimation and comparison made between lap splices and mechanical splices.

Structural Analysis

The structural study of couplers included in the study was the initial design equations given by MSJC. It also includes the earlier design philosophies for lap splices given by NCMA and IBC. The study was also carried out to study the failure of couplers under tensile load and influence of reinforcement couplers on the cracking of reinforced concrete members.

Manufacturing and Specifications [6, 7]

The different steps included in the manufacturing of reinforcement couplers were discussed. The important criterion for the manufacturing is selection of material. The study tells about the material selection for coupler and its installation. A very important aspect of coupler selection is the specifications given for them. Each manufacturer gives its own specification regarding coupler selection. The study includes the specifications of a leading foreign coupler manufacture and Indian specification for selection of couplers given by NCT (National Cutting Tools).

Generally couplers are manufactured from Mild Steel, but in some cases alloys of different metals can also be used. The material should be such that couplers meet the minimum strength requirement (125% of yield strength of rebar). The manufacturing of couplers includes different basic steps as cutting, boring, threading, finishing.

Couplers are manufactured on a metal lathe machine. It rotates the work piece on its axis to perform various operations such as cutting, sanding, knurling, drilling, or deformation with tools that are applied to the work piece to create an object which has symmetry about an axis of rotation. Lathes are used in woodturning, metalworking, metal spinning, and glass-working. Lathes can be used to shape pottery, the best-known design being the potter's wheel. Most suitably equipped metalworking lathes can also be used to produce most solids of revolution, plane surfaces and screw threads or helices. Ornamental lathes can produce three-dimensional solids of incredible complexity. The material can be held in place by either one or two centers, at least one of which can be moved horizontally to accommodate varying material lengths. Other work-holding methods include clamping the work about the axis of rotation using a chuck, or to a faceplate, using clamps or dogs.

The Positional coupler comprises two components, a male section and a female section. The male component has an internal tapered thread and an extended external parallel thread. The female component has a parallel thread and a tapered thread, both of which are internal. All components, including the locknut must be tightened using a torque wrench.

The couplers are installed using following four steps: a) The coupler is normally supplied to a reinforcing bar, ready to be installed and cast in concrete, b) After casting of the concrete and when ready to extend, remove the plastic end cap from the coupler, position the continuation bar in the sleeve and rotate the bar into the coupler, c) Continue to screw the bar into the coupler until tight and d) To ensure correct installation, tighten the joint to the specified torque using a calibrated torque wrench on the continuation bar.

Case study on couplers

A case study was carried out at Jaypee Greens new undergoing project 'Wish Town

Klassic' extended over 40 acres in sector-129 of Noida, India. The Wish Town Klassic has a mix of Duplex & Simplex apartments with 2, 3 & 4 BHK flats, in areas ranging from 1120 Sq. ft. to 2300 Sq. ft. This was a case study of an under construction site where couplers were used in place of lap splices showing the economic advantage of couplers on the normal lap splices.

Total number of columns considered was 14. Size of bars used were 25mm, 20mm, 16mm, 12mm, 10mm in columns only. At the site, lock type couplers were used in the columns only. The majority of couplers used were for 25mm and 20mm diameter bars. Couplers for 16mm diameter bars were used only up to 3rd floor. After that laps were given to 16mm diameter bars. This was done because the use of couplers for short diameter bars was coming out to be uneconomic. Total Number of couplers used was 1182.

Lap Length of 14 Columns

a) By Site Method:

The site method that was adopted for lap splices was based on the grade of concrete. The lap splice was chosen as per the concrete used in the work as adopted on site.

M30 : 46d
M35 : 40d
M25 : 39d

Where d is the diameter of the bar.

b) By IS-456 Method

As a standard method IS 456 specifies a formula for determining the lap length in any structural member. As per IS code lap splice is given by the formula:

$$L_s = 48d$$

Where d is the diameter of the bar.

Estimation

Couplers were installed in Jaypee Greens new undergoing project 'Wish Town Klassic' and their estimation was done. Alternatively, lap splices are calculated for the building. Here lap splices were determined using two methods.

Total length of 25mm, 20mm and 16mm diameter bar was 401.1 m, 453.16m and 52.288 m respectively.

Table 1.0: Calculation of Cost of Lap Splice (Site Method)

Bar diameter (mm)	Weight per meter = 0.0062 * (d * d) [kg/m]	Total steel (length * per m weight)	Total cost (total weight * 45) [Rs.]
25	3.875	1554.2625	69941
20	2.48	1123.8368	50572
16	1.5872	82.9915	3734

Lap length (IS CODE: 456)

Total length of 25mm, 20mm and 16mm diameter bar was 422.4 m, 482.86m and 58.368 m respectively.

Table 2.0: Calculation of Cost of Lap Splice (IS Code Formula)

Bar diameter (mm)	Weight per metre = 0.0062 *(d *d) [kg/m]	Total Steel (Length * Weight per metre)	Total cost (total wt * 45)
25	3.875	1636.8000	73656
20	2.48	1197.54	53889
16	1.5872	92.642	4169

Table 3.0: Calculation of Cost of Couplers

Bar diameter (mm)	Number of couplers (x)	Total cost (36*x)
25	432	15552
20	644	22968
16	114	4104

Rate of reinforcement bar as per New Delhi rates was taken as Rs. 45 per kilogram and rate of a single piece of coupler was taken as Rs. 36.

Then a comparison of the cost was done to determine the amount of money saved by the company in using couplers. This case study indicates the economic advantage of couplers on the normal lap splices.

Comparison

Finally a comparison is made between lap splices and mechanical splices in terms of the strength, economy and feasibility.

Table 4.0: Cost Comparisons in Rs.

Coupler cost	Lap Splice cost (site method)	Lap Splice cost (IS Code)
42,840	1,24,247	1,31,714

Conclusion

This case study has included calculations for only 14 columns whose details were available from the site. This shows that couplers are an effective and an economic replacement of lap splice. This coupler used at the site is known as "tapered thread splice". It is the simplest type of coupler used in the column.

This case study shows how couplers have effectively saved a huge amount of money in a single building. The total couplers cost Rs. 42,840 which is very less than what would have been spent if lapping would have been done by using site method or simply IS specification. This estimation was limited only to the fourteen columns whose details were made available from the company.

The report concludes that the added structural and economic advantages of mechanical splices over laps make the benefit-to-cost ratio extremely attractive because mechanical splices give the structures added toughness and load path continuity that laps cannot offer. The reinforcement couplers not only provide strength to the joints but are they are also an economic means of connections of two bars. The taper-threaded splice is a widely used mechanical splicing system worldwide.

Splices are designed for use on worldwide standard grades of rebar and many international standards. No special high strength, enlarged thread section or increased rebar size is necessary, thus allowing the supply of reinforced bar from multiple sources for maximum cost savings. These splices are the slimmest couplers available today and their innovative taper-threaded design makes them one of the most reliable systems on the market. The taper-threaded splice is a widely used mechanical splicing system worldwide.

The mechanical rebar couplers used on the project quickly and easily connect two pieces of rebar. The couplers use the time-tested, field-proven taper thread for assurance of strength, consistency and reliability while simplifying installation and saving time.

The couplers were considerably more cost effective and time saving than welding the bars together.

References:

[1] James R. Cagley and Richard Apple, "*Economic Analysis: Mechanical Butt Splices vs. Lap Splicing in Reinforced Concrete Construction,"* a study by Cagley and Associates, Rockville, Md., for Erico Inc., 1997.

[2] ACI 318-95, *"Building Code Requirements for Reinforced Concrete,"* American Concrete Institute, Farmington Hills, Mich., 1995.

[3] John W. Wallace, *"Headed Reinforcement a Viable Option,"* Concrete International, ACI, December 1997.

[4] Russell S. Fling, *Practical Design of Reinforced Concrete*, John Wiley & Sons, New York, 1987.

[5] *Influence of Reinforcement Couplers on the Cracking of Reinforced Concrete Members*, Vidmantas Jokūbaitis1, Linas Juknevičius

[6] Masonry Standards Joint Committee: *Building Code Requirements for Masonry Structures*, 2002.

[7] Masonry Standards Joint Committee: *Building Code Requirements for Masonry Structures*, 2005.