International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 06, June-2019

# Flexural Analysis of RCC Rectangular Beam Using Welded Lapping and Coupling at Center

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***Abstract— Splicing of bar is inevitable in construction site because continuous rebar is impossible due to short length in manufacturing process for shifting of steel is easier or required length of steel is not available. The continuity of steel is required in reinforced concrete structure as steel is used to transfer the tension and shear forces but splicing of bar having many imperfections such as improper lapping length, increase in cost of construction, congestion for concrete etc. So for connecting the bars there is an alternate method called the coupler.***

***This study is focused on the flexural behavioral of beam by using welded lapping and coupling for steel rebar. For getting the desired result the experimental study was done with casting reinforced concrete beam. This study will also focus on comparison of conventional lapping, welded lapping and couplings with respect to costing, labours work, flexural strength by applying the point load at center. As center point load gives the maximum stress at center. The experiment will established the results as curing of beam after 7 days, 14 days and 28 days. The comparison of these beams revels the exact flexural strength, lapping length cost and ease of doing work. The steel quantity gets reduce with effective numbers when we will use coupler. A conventional lapping consumes more steel as whole RCC building taken in account.***

***Keywords: Flexural Analysis, Couplers, Welded splices Convectional Lapping, Beam Analysis***

## 1 INTRODUCTION

In early twentieth century the steel has been commonly used as structural building material. The construction industry has trumondsly changes after using the steel as the construction material. Adequate bond formed between steel and concrete as the concrete good in compression and the steel is good in tension that's why the combination of both gives strength and stability to structure. As for continuous reinforcement the joining bar is necessary. Therefore For connecting two steel reinforcing bars, lap Splicing has become the traditional method. But the Lap Splicing has many Disadvantages like higher costing, more congestion, time consuming And other disadvantages. The lap splicing does not give load path continuity independent of condition of the concrete also not really reliable in cyclic loading. The Coupler system i.e. Mechanical threaded coupler is used to connect two bars in the field or site easily as well as quickly. Therefore threaded coupler can be most effective as it gives easy design parameters, easy in installation, reduce the extra costing for steel, and reduce congestion of steel in structure. The mechanical splicing does away with the tedious calculations needed to calculate proper lap length, and there potential errors. Because mechanical splices use less rebars as no lapping, reducing material cost.

As the slab, columns, beams and many RCC structure like bridge having bar diameter above 20mm and larger span the conventional lapping is not convenient as more steel congestion and having higher costing therefore in that manner Mechanical splicing coupler is the best way to bind the two rebars with easy installation and having no compromise with strength.

As per above discussion there are only three basic types of splicing, these are

### 1.1 Convectional lap Splices

Figure 1.1 - Convectional Lapping

The lap splicing is not a regular parameter when we design a RCC member. The lap splicing is inevitable. Lapping of bar or splicing being a point of weakness, it is a way of unfortunate failure. Therefore required care should be taken while providing the splice. Mostly lapping is done less than 36 mm diameters of bars. To transfer the force form one bar to another or the length desired for developing full bar strength is called the lap length i.e. development length. Most of the cases it is recommended that for lapping the length of the bar should be taken by development length.

### 1.2 Welded splices

Figure.1.2 - Butt Welded splices

This is another method of lapping called welded lapping as compare to convectional lapping. The lapping by welds requires extra trained workmanship and extra power with some special equipment as in preliminary requirement. This also gives better strength as per code requires. The welded splicing is also good for the big infra projects where the many steel cut pieces are remaining. The cut pieces may increase the costing of the project. It may leads to the wastage of steel. The weld strength must satisfy the desired strength of bar. The lapping in compression reinforcement should be meet the desired strength of the bar. For reinforcement welding the welding in accordance with the I.S.: 2751(79/2). The welding strength is to be assumed 80% of the design strength. And 100% weld strength of mechanical connection. In lap welding the eccentricity problem arises and the probability of failure of surrounding concrete may cause due to kinematic behavior of steel bar at end connections.

### 1.3 Mechanical threading coupler splices

Figure.1.3-Mechanically Threaded Coupler with steel

The Couplers are made up of mild steel. Many manufacturers use TMT bar also for the coupler as strength matters. But when the mild steel have higher carbon content then the strength achieve as per TMT bar. The main objective of the mechanically threaded coupler is to transfer of axial tensile force or compressive force from one bar to another. The test for coupler is for acceptance for standard. These standard are classified into two types

1. Class H type
2. Class L type

The coupler which satisfies the Low cycle fatigue tests are class L type couplers. And that coupler who satisfies the low cycle fatigue as well as high cycle fatigue tests these type of couplers are called as class H type couplers. In regular RCC structures we use class H type couplers because it subjected to high cycle fatigue test and low cycle fatigue test. The structures like bridges, rail bridges, foundations and other machine foundations are used H type couplers.
Therefore the objective of the study is to check the flexural strength and behavior of mechanically threaded couplers and normal bars under tension and also the economic cost comparison for the entire work.

## 2 MATERIAL AND SPECIFICATION

### 2.1 Mechanically Threaded couplers :

The manufacturing process of mechanically threaded coupler involves three different basic patterns or the steps as Cutting, Peeling, and Threading. For this work the mild steel is used for the couplers but in some cases different metals of alloy can be used. The coupler minimum strength must be equal to 125% of the yield strength of the steel bar.
General Information of Mechanically Threaded bars Preparation of Rebar

1. Peeling

A per the required size the end of reinforcing bar is peeled.

2. Roll threading

By rolling create threads on peeling area of rebar.

3. Installation of coupler

After the threading of both the rebars the coupler can be easily installed simple attach to the rebars with tighten the coupler to the rebar.

Table 2.1 – Coupler specification.

| Technical Specifications Of Mechanically Threaded Coupler | | | | | |
|---|---|---|---|---|---|
| Bar Diameter | | 16 | 20 | 25 | 32 |
| External Diameter | d | 25 | 32 | 40 | 48 |
| Coupler Length | L | 45 | 52 | 65 | 80 |
| Threaded Pitch | Pitch | 2.5 | 2.5 | 3.0 | 3.0 |
| Weight(kg) | | 0.09 | 0.20 | 0.31 | 1.02 |

(Source : Lokpal Industries, Noida)

### 2.2 Fine aggregate and coarse aggregates :

The material used for the concrete must match the BIS standards as per the Sieve analysis tests.

Table 2.2 – Sieve Analysis result

| Fine Aggregate | | Coarse aggregate | |
|---|---|---|---|
| **Sieve Size** | % passing | **Sieve Size** | % passing |
| **4.75mm** | 100 | **19mm** | 100 |
| **2.36** | 90 | **12.7mm** | 78 |
| **1.18** | 50 | **9.5mm** | 31 |
| **600 micron** | 25 | **4.75mm** | 0 |
| **300 micron** | 7 | | |
| **150 micron** | 2 | | |
| **Pan** | 0 | | |
| Specific Gravity : 2.650 | | Specific Gravity : 2.650 | |

### 2.3 Steel :

The HYSD steels bars of FE-500 with diameters 16 mm, were used in all experiment as we studied. The diameter we choose for the experiment is randomly as we refer many research paper and we concluded that this size and steel quantity gives us better result. As our beam size is up to 200 X 300 X 1000 mm we provide 2 nos. 16 mm bar at tension side and 2 nos. bar of 10 mm bar at top for stirrups support. Also we provide stirrups at 150mm c/c for shear. As the center point loading may fails shear fails first. The total steel provides is 559 $mm^2$. As per the IS 456:2000 clause no. 26.5.1.1 maximum area of tension reinforcement shall not exceed 0.04bD.

Table No. 2.3 - Properties for steel Rebar

| Sr. no. | Properties | Description |
|---|---|---|
| 1. | Yield Strength | 500 N/mm^2 |
| 2. | Grade | Fe500 |
| 3. | Type | TMT |
| 4. | Carbon content | 0.55 to 1.5% |
| 5. | Thermal Resistance | Up to 600 $C^0$ |
| 6. | Minimum percent of elongation at failure | 14.5% |

### 2.4 Cement :

The Cement is used in concrete as required grade i.e. The ordinary Portland cement has 3 grades like Grade 33, grade 43, grade 53. The grade 53 is used for our m-40 grade concrete and must match the BIS standards. Different manufacturing industries provide 53 grade cement we use cement from Ultratech industry. Their product gives better strength and good setting time with respect to other types of cement.

### 2.5 Water :

The water will used for concrete must have pH value in between 6 to 8. The drinking water contains pH value 6 to 8. This water satisfies the all BIS standard for concrete.

This paper verifies the flexural strength of mechanical splicing sand the welded lapping system. And other issues like costing and ease of doing construction. Different samples were tested under UTM and reports are studied papers were analyze to observed the flexural strength.

## 3 METHODOLOGY

### 3.1 Testing Procedure

After studying the many research papers we select a beam size which is not specific from any paper or I.S. code. We casting RCC beam having size of 200 X 300 X 1000mm. We used doubly reinforced beam for the experiment. With analysis by Limit state method as the splicing, development length and the strength. The percentage of reinforcement was 0.33% for the tension side and 0.113% for the compression side and stirrups provide at 150 mm c/c. On the tension side 2 bars of 16mm diameters are provided and 2 bars at top for the compression side with Stirrups of 8 mm at 150 mm center to center. Concrete as we know is relatively strong in compression and weak in tension. In reinforced concrete member, little dependence is placed on the tensile strength of concrete since steel reinforcing bars are provided to resist all tensile forces. However the tensile forces are to be developed in concrete due to drying shrinkage, rusting of steel reinforcement, temperature gradient and many other reasons. Therefore the knowledge of tensile strength of concrete is important.

Flexural Strength also known as Modulus of rupture (extreme fiber stress in bending), bend strength or fracture strength is a material property, defined as the stress in material just before it yields in flexural test.
The flexural strength represents the highest stress experienced within the material at its moment of rupture. The value of the modulus of rupture depends upon the dimension of the beam and manner of loading. There are two methods for calculating flexural strength of rectangular RCC beam.

1) Center Point Loading
2) Two point Loading

In center point loading method the stress induced in beam is at center is maximum i.e. It will give maximum result for Moment of rupture as the bending is maximum at center. In that manner we place the Mechanical Threaded Coupler at the Center of bottom bars and the other type which is casted by using Butt welds for connecting the bars at the center with same reinforcement like other mechanically coupler specimen.


Figure 3.1 - Moulds with casted Beam

For casting the beam we select the M-40 grade concrete.

Figure 3.2 -Testing of beam

The flexural teting is done by the IS 516 :1959. The Beam immediately taken for testing as it remove from curing. The of placing bo beam with two rollres at bottom having equidistance from the center. The beam place smoothly as no extra support or any other obstruction from bottom. This way the preparation of beam was done. We perform Cenetr piont loading because we apply coupler at mid span of the beam. As our aim is to find out the coupler strength for maximum stress. The flexural strength occures at highest bending moment setcion thats why we select center point loading for desired result. We did not break complete beams i.e. we are not demolished complete beam we only concern about the peak load that beam can carry. After the beam failure load automatically decreases then we release the macine and take the reading. Each beam having three samples i.e. 7 day curing we tested 3 samples same for 14 and 28 day for coupler and welded splicing beam. As per the mannual given by UTm machine UTM is of confirming IS 516:1959 with loading capacity of 1000kN. As per IS 516:1959 the loading for the flexural strength is 0.7 kg/cm^2.

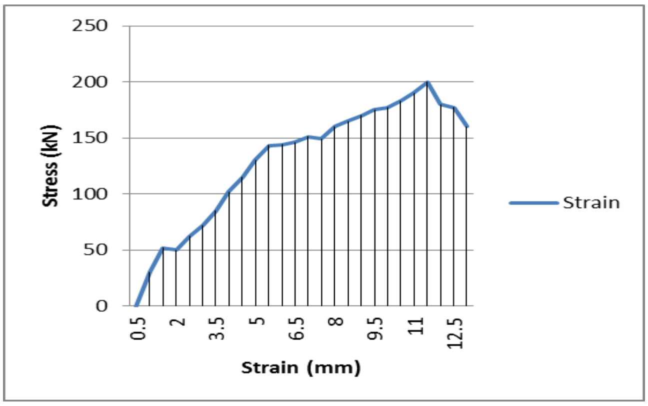
## 4 RESULT & DISSUSION

By performing the experiment we get the observations (reading) and result is as follows as first table of observation is for welded beam and second for the coupler beam both gives observation of peak load at which beam fails for flexural. The graph figure gives

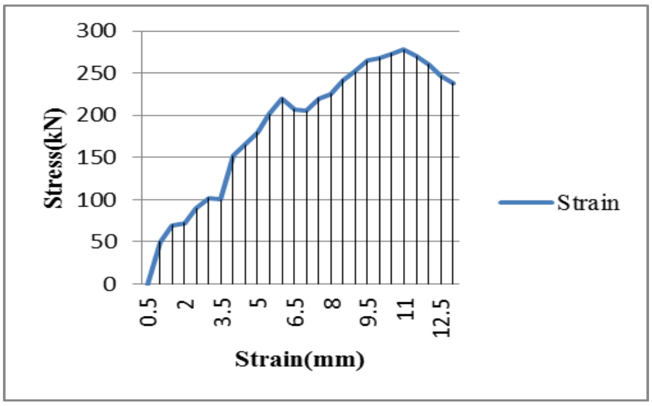
### 4.1 Observations

Table No. 4.1- Observation table for welded beam and coupler beam

| Days of Curing | Specimen | Apply load ($kN/mm^2$) | Avg. Load ($kN/mm^2$) | Flexural Strength | % Reinforcement |
|---|---|---|---|---|---|
| 7 | BW7-1 | 140 | 138.33 | 7.685 | |
| | BW7-2 | 138 | | | 0.33 |
| | BW7-3 | 137 | | | |
| 14 | BW14-1 | 158 | 158.33 | 8.79 | |
| | BW14-2 | 162 | | | 0.33 |
| | BW14-3 | 155 | | | |
| 28 | BW28-1 | 192 | 190 | 10.55 | |
| | BW28-2 | 190 | | | 0.33 |
| | BW28-3 | 188 | | | |
| **Curing days** | **Specimen** | **Apply load ($kN/mm^2$)** | **Avg. Load ($kN/mm^2$)** | **Flexural Strength ($N/mm^2$)** | **% reinforcement** |
| 7 | CW7-1 | 192 | 193.667 | 10.27 | |
| | CW7-2 | 199 | | | 0.333 |
| | CW7-3 | 190 | | | |
| 14 | CW14-1 | 213.5 | 211.83 | 11.86 | |
| | CW14-2 | 210 | | | 0.33 |
| | CW14-3 | 212 | | | |
| 28 | CW28-1 | 277.3 | 281.9 | 15.40 | |
| | CW28-2 | 288.4 | | | 0.33 |
| | CW28-3 | 280 | | | |



(Figure 4.1 – 28 Day Curing Welding Beam)



(Figure 4.2 – 28 day curing Coupling beam)

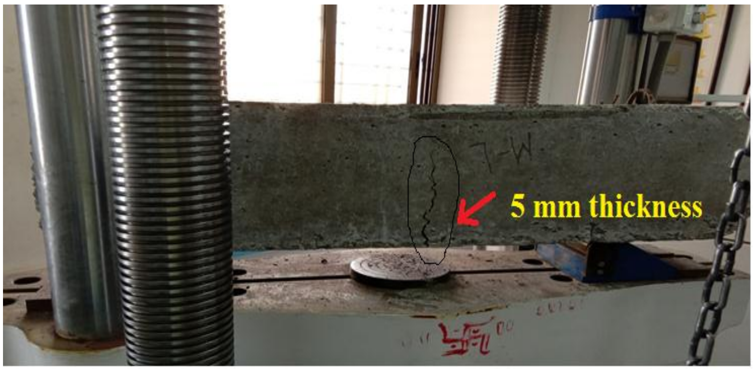



Fig. 4.3 -Testing of beam at 60% loading of welding

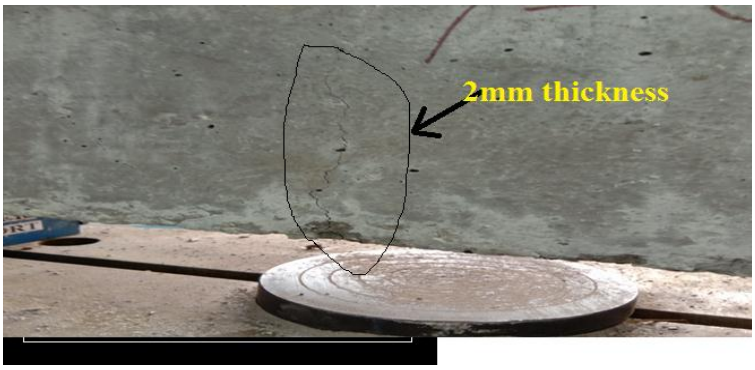



Fig. 4.4 - Testing of beam At 60% loading for Coupling

### 4.2 Cost analysis

A Cost analysis has been done based on steel saving in lapping which indicates that the couplers are cost effective compare to the lap splicing. Hence mechanical splices such as threaded couplers can be very effective since they ease the design parameters, easy installation, and also reduce the amount of reinforcement required and thus saving a huge amount of money in a single joint. As developer can use waste bar as that bar was not use anywhere as length is short enough to handle total continuous span. The total cost save per joint with counting wastage steel is way far less than what would have been spent if lapping would have been as per I.S. 456-2000 specifications. As we visit the some sites they use the lapping length as per the '$L_d$' development length for safer side and give extra spiral reinforcement for shear safer side.

On the other hand we also conclude that the cut pieces of steel bars can be reused by using the coupler as the coupler give the desired strength as per the continuous rebar. In site condition many cut pieces of steel were waste because of improper cut length this effects entire project cost.

As constructional steel or TMT bars are made up of wastage of steel. The waste steel is melt with high melting temperature by using the coal. This process is also effects the environment imbalance as the coal is not a manmade product. It is natural mineral and it is limited stock. Second thing the burning of the coal may produce many hazardous gases that also harmful to our nature. So the proper use of mechanically threaded coupler

## 5 CONCLUSION

Based on the study and paper observation many conclusions are taken in account

- As we take Butt welded splice for lapping rebar and other is mechanically threaded coupler the coupler gives 32-38% greater Flexural Strength as per our experiment.
- From above experiment the failure pattern of the welded splice beam is brittle as it is shown in graph. And that of coupler the failure pattern is ductile but the beam of coupler may indicate the shear cracks on both the side before flexure. As per my experience and my testing result the shear crack appear first than flexural cracks.
- Couplers offer quality, cost and time saving. Fixing couplers requires no special skill or equipment. Simple mechanical ways in adopting mechanical splicing compared to lapping, accelerates construction schedule for optimum cost and efficiency.

The Mechanical Threading couplers are the best option for lapping as it is the convenient method as compare to other methods like convectional lapping and welded lapping.

**ACKNOWLEDGEMENT**

I WOULD LIKE TO EXPRESS MY SINCERE THANKS TO COL. PROF. DR. N. RAMACHANDRAN, VICE CHANCELLOR AND DR. R.S. TALIKOTI, HEAD OF CIVIL ENGINEERING DEPARTMENT, SANDIP

UNIVERSITY, NASHIK FOR THE SUPPORT SO THAT WE COULD SUCESSFULLY COMPLETE THE PROJECT WORK IN TIME. A BLEND OF GRATTITUDE, PLEASURE AND GREAT SATISFACTION IS WHAT, WE FEEL TO CONVEY OUR INDEBTEDNESS TO ALL THOSE WHO HAVE DIRECTLY OR INDIRECTLY CONTRIIBUTED IN SUCESSFUL COMPLETETION OF PROJECT WORK.

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