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Research Article

Effect of size and arrangement of tension reinforcement on flexural behavior of Reinforced concrete beam

Sunil Raiyani†* and Sonal Thakkar†

†Department of Civil Engineering, Nirma University, SG Highway, Ahmedabad, India

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Abstract

The paper presents experimental work done to understand effect of bar diameter and placement of tension reinforcement on flexure behavior of simply supported beams. Eight beam of 150×250×1500 of M25 grade of concrete and Fe415 grade of steel were cast and subjected to two point load flexure test under universal testing machine as specified in IS516. Deflection was measured at the centre point and at the point of application of load with the dial gauge, to enable load v/s deflection plot. Experimental result indicate that a small change in area of steel and placement of reinforcement place a very vital role in deflection and ultimate load carrying capacity.

Keywords: *limit state method, working stress method, under reinforced section, deflection, ultimate load.*

1. Introduction

Design for any type of structure is govern by three criteria: safety, serviceability and economy. Reinforced Cement Concrete (RCC) structures satisfy all three design criteria and hence are used abundantly for various structural application. Safety along with economy being today governing criteria in design, it is utmost important to predict ultimate load and also to find deflection pattern of structure under particular restrain condition. Experimental analysis being a very powerful tool helps us in understanding actual behaviour of structure under field restrain condition. Two popular methods of design are Working Stress Method and Limit State Method. In working stress method elastic behaviour of steel & concrete is assumed and materials obeyes Hook's law. In Limit State Method acceptable limit for safety and serviceability is consider while design a structural member. There for deflection of any structural member become a governing criteria for satisfying serviceability requirement.

A structure, or any parts should be such that, deflections and cracks are minimum during its entire life of service. Design of RCC structures is of two types that is under reinforced section or over reinforced section. In under reinforced section, the depth of neutral axis is less than the balanced depth of neutral axis. Hence steel will fail first and specimen will go under large deformation giving enough warning before actual failure. While in over reinforced section the depth of the neutral axis is more than balanced depth and hence concrete will fail first leading to sudden failure of structure. As this is brittle failure and hence not recommended by any code.

Byung *et al*. in his experimental studies describes effect of variation on flexural strength of RCC beam containing steel fibers. It was found that as increase in fibres lead to reduction in stress in steel and increase in ductility. Zararis *et al*. carried out studies on shear failure of RCC beam. Sayyad *et al*., described effect of stirrups orientation on flexural response of reinforced concrete beams.

Specific study to evaluate behavior of reinforced concrete (RC) beam element under two point loading with different pattern placement of tension reinforcement and its effect on ultimate load carrying capacity and deflection is not carried out so far. This study aims to bridge the gap between theoretical analysis and practical behavior of RC beam element.

2. Experimental Programme

To understand the failures patterns and to determine ultimate cracking load and deflection, reinforced concrete beams with different reinforcement patterns were cast. The amount of reinforcement under flexure was kept approximately constant for all eight beams. Dimension of the beam was 150×250×1500 mm. The reinforcement pattern for various beams is shown in Fig. 1 & 2. M25 grade of concrete was used keeping constant cover of 25 mm for all specimens. 8 mm diameter bar was used as hanger reinforcement while 8 mm diameter bars were used as stirrups with centre to centre spacing of 100mm.

*Corresponding author: **Sunil Raiyani**

2.1. Concrete Mix Design

Concrete mix design was done according to IS: 10262 2009. Mix design for M25 grade of concrete was done using data given in Table 1. Table 2 shows the final mix proportion of constituents while compressive strength results of concrete mix is tabulated in Table 3.

Table 1 General Design Data

Grade of Concrete	M25
Maximum nominal size of aggregate	20 mm
Slump	75mm
Fine aggregate zone	II
Exposure Condition	Moderate
Specific Gravity of Cement of OPC 53 grade	3.18
Specific Gravity of Coarse aggregate	2.81
Specific Gravity of fine aggregate	2.55

Table 2 Mix Proportions

Grade of concrete		M25		Proportion
Cement (kg/m³)		383.16		1.00
Fine Aggregate (kg/m³)		674.97		1.76
Coarse Aggregate (kg/m³)	20 mm down	717.28	1195.47	3.14
	10 mm down	478.19		
Water (kg/m³)		188.30		0.49

Table 3 Compressive strength of cube at 28 days

	Compressive Strength (MPa) at 28 days
Cube – 1	31.15
Cube – 2	31.28
Cube – 3	32.25
Average Compressive strength (MPa)	**31.56**

2.2. Reinforcement Design

Table 4 shows reinforcement details for beams and longitudinal section for design of reinforcement for each beam is shown in Fig. 1 while cross section of the beams is shown in Fig. 2.

Table 4 Reinforcement Details for beams

Beam Name	Longitudinal Steel	Stirrups Spacing	No. of specimen
B5L10	5-10 Ø	8 Ø - 100mm	2
B2L16	2-16 Ø		2
B2L12 – 2L10	2-12 Ø + 2-10 Ø		2
B2L10 – 2L12	2-10 Ø + 2-12 Ø		2

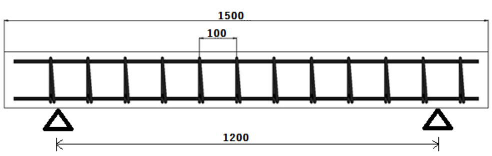
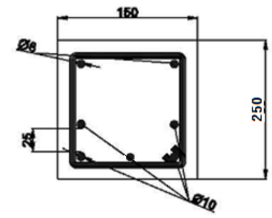
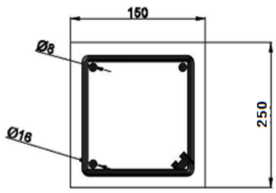


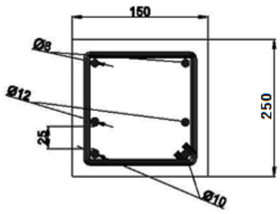
Fig. 1 Longitudinal section of beam



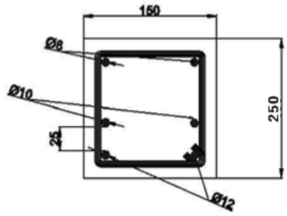
B5L10
(Area of steel – 392 mm²)



B2L16
(Area of steel – 402 mm²)



B2L12 – 2L10
(Area of steel – 383 mm²)



B2L10 – 2L12
(Area of steel – 383 mm²)

Fig. 2 Cross section of beams

3. Test Procedure

1. The beams were cast according to mix design given in Table 2 and were cured using jute bags for 28 days. Flexural testing of the beams was done by application of two point load as per IS 516: 1959[3]. The effective length of each beam was kept as 1200 mm measured from the center of each support. Fig. 3 shows actual test set up.
2. Application of load was done at constant rate and deflection was measured at two points i.e. center point and at point of application of load using dial gauge having least count of 0.001 mm.
3. The beam were loaded until the ultimate load capacity of the beam was reached.

Fig. 3 Test Setup

4. Results and Discussion

4.1 Comparison of load v/s deflection

Two point load flexure test was carried out on all eight beams and graph of load v/s deflection was plotted as shown in Fig. 4.

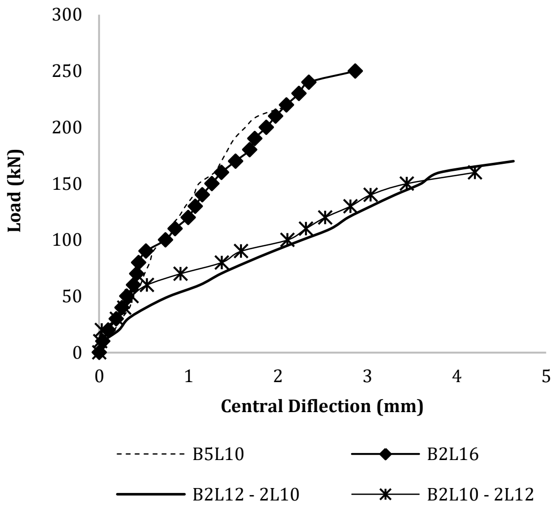


Fig. 4 Load v/s deflection of different beams

As observed from Fig. 4, deflection in B2L12 – 2L10 and B2L10 – 2L12 beam was approximately 40% more than B5L10 and B2L16 beam, hence it is deformed by large amount. Thus these beams will give enough warning before actual failure and are more suitable for construction work. Fig. 4 also shows that load carrying capacity of beam B5L10 and B2L16 was nearly 33% more than B2L12 – 2L10 and B2L10 – 2L12 beams.

4.2 Comparison of Ultimate Moment

Average area of steel is taken as 390 mm² for the calculation.

1) Limit state method [1]:

$$x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b} = 82.62 \text{ mm}$$

$f_y = 415\text{MPa}$
$f_{ck} = 31.56\text{MPa}$
$b = 150\text{mm}$
$d = 225\text{mm}$
$A_{st} = 390\text{mm}^2$

$$x_u < x_{lim} = 0.48 \times d = 108$$

Under reinforced section (URS)

$$M_u = 0.87 \times f_y \times A_{st} \times (d - 0.42 x_u) = 26.80\,\text{kNm}$$

2) Working stress method:

$$\frac{bx^2}{2} = mA_{st}(d - x)$$

m = 8.87 (modular ratio as per IS: 456 [1])

$$x = 81.38\text{mm}$$

$$x > x_{bal} = 0.288d = 65\text{mm}$$

Over reinforced section (ORS)

$$M = \frac{\sigma_{cbc}}{2} \times b \times x \times (d - \frac{x}{3}) = 12.70\text{kNm}$$

Table 5 Ultimate moment comparisons

Beam/Method	Limit state method (URS) (kNm)	Working stress method (ORS) (kNm)	Experimental result of ultimate moment (kNm)	Experimental result of cracking moment (kNm)
B5L10	26.80	12.70	44	26
B2L16			50	34
B2L12 – 2L10			32	24
B2L10 – 2L12			34	22

From the Table 5, it can be observed that ultimate bending moment in actual section designed using limit state method is at par with cracking moment in beams. But when it is designed using working stress method large variation in moment was observed as compared to experimental results. This shows that design of section using limit state method gives more appropriate results compared to design by working stress method.

4.3 Cracking patterns

Crack patterns of various beams is shown in Fig. 5. The first crack for B5L10 and B2L16 beam appeared in pure bending zone, while first crack for B2L12 – 2L10 and B2L10 – 2L12 beam appeared in shear – bending zone. Thus from cracking pattern importance of placement of tension reinforcement can be visualized. It can be observed from Table 4 that Beams B5L10 and B2L16 have 4.7% increase in steel area compared to B2L12-2L10 and it results into 36% increase in load carrying capacity with 35. 71 % decrease in deflection. In beams B2L16 with 2.5% increase in area of steel more ultimate load and greater deflection was observed compared to B5L10.

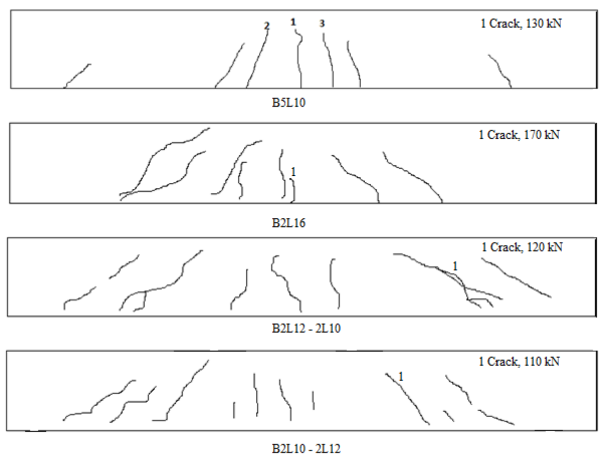


Fig. 5 cracking pattern of beams

Conclusion

1. Beams having lesser area of steel on tension side, showed more deflection. Deflection increased up to 40% leading higher warning before actual failure.
2. Load carrying capacity increased for beams having higher steel by appreciable amount. Thus economically beams with larger diameter on tension side is preferred as it will lead to 33% more load carrying capacity.
3. Beams with lesser area of steel show more cracks in tension zone indicating yielding occurring in steel.
4. It can be concluded that for main beams in structural system where greater deflection will prove beneficial, bars of smaller diameter should be placed on tension side while in secondary beams where load carrying capacity is important bars of greater diameter should be place on tension side.

Acknowledgement

The authors are thankful to Civil Engineering Department, Institute of Technology, Nirma University, Ahmedabad to carry out the project.

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