Experimental Study of Flexural Behavior of Simply Supported Homogenous and Partial Rcc Beam

Arvind Proch

Abstract— **The experiment is aimed at investigating the flexural strength of partial and homogeneous beams and studying the cracks appearance at the interfaces and failure modes. A beam is a one dimensional (normally horizontal) flexural member which provides support to the slab and vertical walls. In a normal beam (simply supported) two zones generally arise, that is. Compression zone at the top and tension zone at the bottom. As we know that concrete is weak in tension and steel is introduced in the tension zone to take up the tension, but as strength of concrete is ignored in tension zone with respect to compression zone. So logically there is no concrete is required in the tension side. This concrete needs to be provided on the tension side to act as strain transferring media to steel and called as 'sacrificial concrete' Baring strain transferring issue, If this concrete has no tension then why we go for same grade of concrete which is used in upper zone? This is the basic question which led to the idea of concrete grade reduction in tension zone for RCC beams to reduce construction cost. The required tests were carried on in order to check the performance of the beams casted with the variation of grade of concrete in tension and compression zone. The test results were encouraging enough with the reduction in cost compared to the normally casted homogeneous beams. Eight beams were casted to achieve the objectives of this research. In this research we used four controlled (homogeneous) beams two of M25 and two of M30, and four partial beams in two different combinations that is, in first combination we used M25 in compression zone and M20 in tension zone and in second combination we used M30 in compression zone and M20 in tension zone. It was also found that there is not very large difference in flexural strength of homogenous and partial beams. So, the partial beams using lower grade of concrete in tension gave better results. The use grade variation in beams will not only results in achieving economy but also save on environmental degradation by minimizing the use of cement (decreasing the emission of Co2 produced during cement production).**

I. INTRODUCTION

A reinforced concrete flexural member should resist compressive, shear and tensile stresses induced in it by loads acting on the member. Concrete is somewhat strong in compression but very weak in tension. Plain concrete members thus have limited carrying capacity owing to low tensile strength. Steel is very strong in tension. Thus tensile weakness of concrete is overcome by provision of reinforcing steel in tension zone round the concrete to make a reinforced concrete member. There are various reinforced concrete flexural members i.e. slab, wall, beam etc. The basic approach of design of a flexural member is the same whereas details may differ. Here we are restricting ourselves to flexural behavior of reinforced concrete beams. A beam is a one dimensional (normally horizontal) flexural member which provides support to the slab and vertical walls. In a normal beam (simply supported) two zones are encountered viz. compression zone at top and tension zone at bottom. As we know concrete is weak in tension and steel is introduced in the tension zone to take up the tension, but as strength of concrete is ignored in tension zone with respect to compression zone, logically no concrete is required in tension side. This concrete needs to be provided on tension side to act as strain transferring media to steel and may be called as 'sacrificial concrete'. If this concrete has no function mere than strain transferring, then why we go for same grade of concrete which is used in the upper zone? This is the basic question which led to the idea of concrete grade reduction in tension zone for RCC beams to reduce construction cost. In the ancient times size of walls was large especially in load bearing structures. With the advances in the science and technology Reinforced Concrete Construction (R.C.C) came in to picture. Initially according to Indian standard code of practice IS 456-1978, M15 grade of concrete was permitted to general construction. As per new revision made in IS 456-2000, M20 grade of concrete can be used for mild construction environment. With the help of innovation, imagination, full understanding and keen observation of structures, scientific knowledge of various aspects of the structures, many dynamic personalities in civil engineering field are coming with new concepts with the help of which there are lots of findings i.e. Reduction in thickness of wall, reduction in beam-column sizes and many more. But no research or study has been made yet on replacement of sacrificial concrete in case of deep beams. This is a burning topic in the structural design. As we know concrete is weak in tension, to take this tension, steel is provided in the bottom side of the beam. Compressive stresses are induced in the zone above the neutral axis, compressive strength of the concrete lying above neutral axis is an important aspect. This induces compressive force in the top zone at a distance of 0.42 Xu. Where Xu is the Neutral axis distance from top of section

Manuscript received July 09, 2015
Arvind Proch, M.tech student from Kurukshetra University

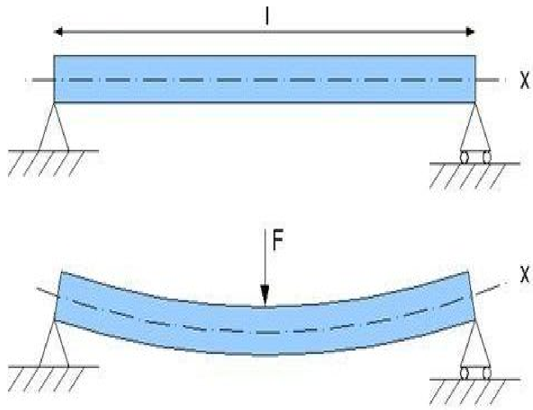

Figure 1.1: Behavior of Beam under Loading.

The neutral axis is an axis in the cross section of a beam or shaft along which there are no longitudinal stresses (strains). If the section is an isotropic, symmetric and is not curved before a bend occurs, then the neutral axis is at the geometric centroid. Fibers on one side of the neutral axis are in a state of tension, others on the opposite side are in compression.

The tension force acts at centroid of steel reinforcement provided at bottom of section. If we consider a simply supported beam subjected to bending under factored load. For equilibrium, total compression must be equal to tension. The applied bending moment at collapse, that is factored bending moment is equal to resisting moment on section provided by internal stresses. This is called ultimate moment of resistance. The distance between the point of action of compressive force and tension force is called lever arm and it is directly proportional to moment of resistance.

As structural engineers we should concentrate on the structural and functional design of the structure. But, economy of the project is also a major factor. Keeping economy and safety of the structure in mind, we came up with the concept of "Partial Beam".

A partial beam is a normal beam casted using two different grades of concrete, one above and other below the neutral axis. Partial beam is a beautiful result of the application of engineering in building construction works to achieve economy as well as reduction in the environmental impact due to construction works. The purpose of this research is to find out effect of using variation of grade of concrete in compression and tension zone in RCC beams on parameters like flexural strength, cracks pattern and failure modes of RCC beams.

II. EXPERIMENTAL PROGRAM

2.1 Methodology

The experimental program mainly consists of two parts, viz., preparation of the required types of specimens and testing the same. The experimentation is aimed at studying flexural strength of partial beam and studying the crack appearance at the interfaces. The quality as well as the characteristics of the concrete depends on the properties of its ingredients. Hence the preliminary tests were conducted on cement, coarse aggregate and fine aggregate before the commencement of the experimental programme. The designed mix proportions for M30, M25 and M20 grade of concrete are shown in Table below

M20

Water	Cement	FA	CA	
191.58	348.327	616.218	1219.14	By mass
0.55	1	1.76	3.5	Absolute volume

M25

Water	Cement	FA	CA	
186	372	592.90	1228.91	By mass
0.50	1	1.59	3.30	Absolute volume

M30

Water	Cement	FA	CA	
186	413.34	571.36	1227.37	By mass
0.45	1	1.38	2.96	Absolute volume

Beam analysis

Beams dimensions =175mm×300mm× 1450mm

Concrete M 25 and steel Fe500

Limiting value of tensile reinforcement is given by equating the force of tension and compression

$0.87\ f_y A_{st} = 0.36\ f_{ck} b x_m$ --------- (a

Where,

F_y = characteristic strength of steel

A_{st} = limiting area of steel

f_{ck} = characteristic strength of concrete

b = width of beam

X_m = maximum value of depth of neutral axis

For M25 and Fe 500

f_{ck} = 25 MPa

f_y = 500 Mpa

From equation (a)

$$Astcal = \frac{0.36 f_{ck} b X_m}{0.87 f_y}$$

$$= \frac{0.36 \times 25 \times 175 \times 0.46 \times 264}{0.87 \times 500}$$

$= 439.70\ mm^2$

According to clause of 26.5.1.1 of IS: 456-2000, the minimum tension reinforcement is given by

$$Ast,\ min = \frac{0.85bd}{fy}$$

$= 78.5\ mm^2$

Also according to clause of 26.5.1.1 of IS: 456-2000, the maximum tension reinforcement is given by

$A_{st,\ max} = 0.04bD$

$= 0.04 \times 175 \times 300$

$= 2100\ mm^2$

So $A_{stmin} < A_{stcal} < A_{stmax}$ Ok.

Provide 3 bars of 12 mm dia. and 1 bar of 8 mm dia

Total area provided = 389.24 mm² < 439.70 mm

$$Pt\ \% = \frac{100 \times Ast}{b \times d}$$

$$= \frac{100 \times 389.24}{175 \times 264}$$

= 0.84 %

DEPTH OF NEUTRAL AXIS

Depth of N.A is obtained by considering equilibrium of normal forces.

Force of compression = force of tension

$0.36 f_{ck} bx = 0.87 f_y A_{st}$

$$X = \frac{0.87 fyAst}{0.36 fckb}$$

$$X = \frac{0.87\times500\times389.24}{0.36\times25\times175}$$

= 107.5 mm

For Fe 500,

Xm = 0.46d = 0.46×264 = 121.44 mm

Therefore x < Xm ok.

Therefore depth of neutral axis=107.5 mm.

This section is under reinforced.

Therefore moment of resistance is w.r.t to steel.

$MOR = 0.87 f_y A_{st} z$

Where z is lever arm (The distance between the points of action of compressive

Force and tension force is called lever arm and given by

Z = d - 0.42X

= 264 – 0.42×107.5

= 218.85 mm

MOR = 0.87× 500× 389.24 ×218.85

= 37.06KNm

W_u = dead weight of beam per meter run

= 0.3×0.175×25 = 1.31 KN/m

Taking moment about centre

$$(W+ Wu \frac{l}{2})\times \frac{l}{2} - w\times0.2 - Wu\times0.65\times\frac{0.65}{2} = Mu$$

$$(W+ 1.31 \frac{1.3}{2})\times \frac{1.3}{2} - w\times0.2-0.211\times1.31 = 37.06$$

0.45W+0.553-0.276=37.06

W = 81.74 KN

Reactions of beam

$R_A = R_B$ =W+0.85 = 82 KN

Factored shear force = 82 KN

Percentage area of longitudinal steel

Pt % = 0.84%

From table no.19 of IS: 456-2000, for M25 and $\mathbf{P_t}$% = 0.84%

τ_c = 0.60 MPa

Where, τ_c = shear strength of concrete

Also nominal shear stress is given by

$$\tau_v = \frac{Vu}{bd}$$

$$= \frac{82\times1000}{175\times264}$$

= 1.77 MPa

Also from table no. 20 of IS: 456-2000

Maximum shear stress, $\tau_{c\,max}$ = 3.1MPa

Therefore $\tau_v > \tau_c$ not ok

Therefore shear reinforcement is to be provided.

Strength of shear reinforcement

$V_{us} = v_u - \tau_c bd$

= 82×1000 – 0.6×175×264

= 54280N

Adopt 8mm 2 legged vertical stirrups

Therefore, $ASV = 2\times \frac{\pi}{4}\times 8^2$

= 100.48 mm^2

Therefore spacing of shear reinforcement is given by

$$Sv = \frac{0.87\times500\times100.48\times264}{54280}$$

= 212.59 mm

Adopt spacing of 200 mm

≥ 100mm ok

<300mm ok

Minimum area of stirrups

$$A_\circ \geq \frac{0.4 bSV}{0.87\times fy}$$

$$A_\circ \geq \frac{0.4\times175\times100}{0.87\times500}$$

= 16.01 mm^2 < ASV

Summary of the Beam Sections

DETAILS	TYPE H1 AND P1M25	TYPE H2 AND P2M30
Main Reinforcement	3#12mm	4#12mm
Percentage Steel (pt)	0.84%	1.09%
Hanger Bars	2#8mm	2#8mm
Stirrups	2legged#8mm @200mmc/c	2legged#8mm @150mmc/c
Anchor bars	2#8mm	2#8mm

III. EXPERIMENTAL PROGRAM

Separate mix design was prepared for M20, M25, and M30 grade of concrete. The formwork prepared and ingredients are weight balance. Ingredients are mixed with the hand mixing. In this research we used four controlled (homogeneous) beams two of M25 and two of M30, and four partial beams in two different combinations that is, in first combination we used M25 in compression zone and M20 in tension zone and in second combination we used M30 in compression zone and M20 in tension zone. Concrete was placed in the formwork in layers of approximately 10 cm compacted and vibrated. Similarly, the layers were successively paced one above the other compacted and vibrated. Each end faces were properly compacted to get smooth finish. After completion of about 10hours, wet gunny bags were placed on the newly casted beam. For partial (composite) beams the neutral axis is marked on the moulds. Concrete in the tension zone was placed in the formwork in the layers of 10 cm compacted and vibrated firstly for M20 grade of concrete. Similarly the layers were succeThe load was applied at the mid-span by a manually controlled hydraulic jack and the load was distributed to the beam by load spreader. The applied load was measured by load cell. Deflections in the beam during testing were observed by means of dial gauge. The dial gauge was provided at mid span to measure deflections with varying loading. In this research the deflection was measured after each 2.5ton load. Load at the first and subsequent cracks and also the ultimate or maximum load were recorded. The ultimate load was the load that the beam can sustain before failure. Mode of failure and crack or rupture patterns were observed and identified after the beam failed. The cracking patterns were drawn on a paper, based on the grid lines that have been drawn on the beam surface. The data for all the tests were obtained and the curves of load versus deflection were plotted. Any defects to the beams before testing were recorded systematically. Vertical alignment of the beam configuration was frequently monitored to ensure that there was no lateral movement occurred during testingssively placed on above the other compacted and vibrated. After the level of neutral axis, the concreting operation was stopped with M20 grade of concrete and started with M25 and M30 respectively.

The summary of load taken at first crack and at bending is shown in table below.

Table 6.1: Crack Propagation and Failure Load

S.NO	BEAM DESIGNATION	FIRST CRACK LOAD (KN)	LOAD AT BENDING FAILURE (KN)	MAXIMUM DEFLECTION (MM) (at load in) KN)
1	H1M25-I	85	180	1.83 (225)
2	H1M25-II	96	192	1.78 (225)
3	P1C25T20-I	75	182	1.71 (225)
4	P1C25T20-II	85	185	1.93 (250)
5	H2M30-I	104	250	2.01 (250)
6	H2M30-II	93	265	1.98 (250)
7	P2C30T20-I	88	230	1.91 (250)
8	P2C30T20-II	81	225	1.86 (250)

The summary of location of neutral axis (NA), moment of inertia (MOI), crack pattern, ultimate load and flexural strength is shown in Table.

Table: Flexural Strength of Beams

S.NO	Beam	Moment of inertia (mm^4)	Location of NA from bottom, Y_{max} (mm)	Ultimate moment (kNm)	Flexural strength (N/mm^2)	Crack pattern
1	H1M25-I	3.94×10^8	193	45.05	22.07	F
2	H1M25-II	3.94×10^8	193	41.28	20.22	F-S
3	P1C25T20-I	3.94×10^8	193	45	22.04	F
4	P1C25T20- II	3.94×10^8	193	35.53	17.40	F-S
5	H2M30-I	3.94×10^8	185	60.32	28.32	F
6	H2M30-II	3.94×10^8	185	59.52	27.95	F
7	P2C30T20-I	3.94×10^8	185	57.2	26.86	F
8	P2C30T20- II	3.94×10^8	185	55.89	26.24	F

CONCLUSION

The following conclusions can be drawn from this study:

- All types of beams (homogeneous and partial beams) showed almost same deflections.
- The ultimate bending moment remains almost same whereas bending moment at first crack varies.
- All type of beams have shown flexural and shear cracks. In six beams, the cracks at failure are flexure failure whereas in two beams, crack at failure are flexure- shear failure. This may be because of smaller shear span of the test specimen.

- The flexural strength of homogeneous and partial beams are almost same.
- No presences of cracks were seen at interface of two grades of concrete but theoretically there are the chances of failure at interface.
- Finally comparison between general and partial beam can be made in "EEE" Format as-

E- Engineering –Attainment of strength without compromising the serviceability.
E-Economy - Reduction in overall cost of construction (by nearly 7-11%)
E-Environment-Reduction in impact on environment (by decreasing the emission of CO_2 produced during cement production)

REFERENCES

JOURNAL PAPERS

[1] **B S Karthik, Dr.H.Eramma& Madhukaran.** "Behavior of concrete grade variation in tension and compression zones of rcc beamsInternational Journal of Advanced Technology in Engineering and Science Volume No.02, Issue No. 07, July 2014.
[2] **G. Venkatesan, S. Reghu Raman and M. Chandra Sekaran**, "Flexural behaviour of reinforced concrete beams using high volume fly ash concrete confinement in compression zone" Journal of Civil Engineering (IEB), 41 (2) (2013) 87-97.
[3] **S. B. Kandekar, P. D. Dhake and M. R. Wakchaure**, "Concrete grade variation in tension and compression zones of RCC beams" IJIRSET, ISSN: 2319-8753, Vol. 2, Issue 8, August 2013.
[4] **Vidula S. Sohoni, M.R.Shiyekar**. ", Effect of Change in Grade of Concrete on the Composite Members of a Framed Structure" International Journal of Engineering Research and Development, Volume 2, Issue 6 (August 2012), PP. 35-41.
[5] **R.V. Balendran, A Nadeem,T Maqsood, T.M. Rana,** "Parametric study on the flexural behavior of plain concrete beams strengthened by externally bonded plates", CI-Premier PTE LTD, August 2001.

BOOKS

[1] **Shetti. M. S**. (2003), Concrete Technology theory & Practice, S.Chand & company (P) Ltd Publishers, New Delhi.
[2] **Gambhir. M.L**. (2010), Concrete Technology theory & Practice, Tata Mcgraw Hill Education Private Limited, New Delhi.
[3] **Neville, A.M** (1995). Properties of concrete, Pitman Publishing Ltd., London.
[4] **Dr. B.C. Punmia,A.K. Jain,A.K. Jain**(2014), R.C.C. Designs, Luxmi Publications , New Delhi.
[5] **Shah, Karve** (2014), Limit State Theory and Design of Reinforced Concrete, Structures Publications, Pune.

IS CODES

[1] **IS: 456 – 2000**: "Code of Practice for plain and reinforced concrete". Bureau of Indian Standard, New Delhi.
[2] **IS: 10262 – 2009**: "Indian Standard Concrete Mix Proportioning" – Guide lines. Bureau of Indian Standard, New Delhi
[3] **IS: 383-1963**: "Indian Standard Specification for Coarse and Fine Aggregate from Natural Sources for Concrete", Bureau of Indian Standard, New Delhi.
[4] **IS: 8112-1989**: "Specification for 43 Grade Ordinary Portland Cement". Bureau of Indian Standard, New Delhi.
[5] **IS: 5816-1999**: "Method of Test for Splitting tensile strength of concrete cylinders". Bureau of Indian Standard, New Delhi.
[6] **IS: 1199-1959**(Reaffirmed 2008): "Method of sampling and Analysis of Concrete". Bureau of Indian Standard, New Delhi.
[7] **IS: 9103-1999**(Reaffirmed 2008): "Concrete Admixtures-Specification" Bureau of Indian Standard, New Delhi.
[8] **IS: 516-1959**(Reaffirmed 2008): "Method of test for strength of concrete" Bureau of Indian Standard, New Delhi.