FLEXURAL BEHAVIOUR OF HIGH STRENGTH RCC BEAMS WITH LOWER GRADE CONCRETE IN THE NEUTRAL AXIS ZONE

Tarak Mathew George[1], Vincy Koshy[2]

[1]*Tarak Mathew George, P G Student, Dept. of Civil Engineering, Saintgits College of Engineering, Kerala, India*
[2]*Er Vincy Koshy, Asst Professor, Dept. of Civil Engineering, Saintgits College of Engineering, Kerala, India*

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Abstract - *Concrete is widely used as one of the important construction material. It is well recognized that prediction of concrete strength is important in modern concrete constructions and in engineering judgments. The concrete just above the neutral axis is less stressed where as the concrete below the neutral axis serves as a shear transmitting media. For any construction safety and economy is a huge factor so the key to a successful project is finding a balance in these two parameters. In concrete beams, strength of concrete lying near the neutral axis is not fully utilized.*

In the present study , the reinforced concrete beams was divided into 3 layers : bottom layer, middle layer and top layer. In the initial phase a high strength concrete beam of grade M70 throughout the cross section was casted and tested. Thereafter by replacing the M70 concrete in the middle layer by M20 grade concrete, a number of beams were casted with different thickness(100, 90, 80, 60, 40 mm).The variation in thickness of middle layer was based on the stress block diagram given in Indian standard code, from which the optimum thickness of the middle layer of lower grade concrete (M20) is found out. Then the flexural strength of these heterogeneous beams were found out using loading frame and compared with flexural strength of control beam. The effect of on ductility were also studied.

The test results indicated that the beam having 60 mm middle thickness with M20 grade concrete and 50mm top layer and 140mm bottom layer of high strength M70 grade concrete as the optimum replacement for a typical M70 beam. The optimum beam also was found to be cost effective as material required for the casting of the same was reduced.

***Key Words*: Neutral axis, ,High strength, Flexural behaviour, Heterogeneous Beam.**

1. INTRODUCTION

Reinforced cement concrete is one of the important materials in the construction industry. Now a days the use of concrete is increasing very much. However there is acute shortage of raw materials for its preparation. Lot of researches were carried out for the investigation of alternative methods that can be used in concrete which can reduce the consumption of cement in concrete.

In case of simply supported reinforced concrete beam, the neutral axis divides the tension zone and compression zone. The region below the neutral axis is in tension and the region above neutral axis is in compression. Since concrete is weak in taking up tension, steel reinforcements are provided at the tension zone of the beam. The concrete below the neutral axis act as the medium for transferring stress from compression zone to the tension zone. So the concrete provided below the neutral axis is known as sacrificial concrete. The compressive force is acting in the top zone at a distance of 0.42Xu from the top of the beam section ,where Xu is the neutral axis distance from top of section. The strength of concrete near the neutral axis is not fully utilized. Also the concrete just above the neutral axis is less stressed where as the concrete below the neutral axis serves as a shear transmitting media. Thus a lower grade concrete can be used in the neutral axis zone.

So in present investigation, a typical high strength RCC beam is compared with heterogeneous high strength RCC beams which has a lower grade concrete in the neutral axis zone. The thickness of the lower grade concrete is varied based on IS code stress block parameter of a typical beam. In order to understand the effect of lower grade concrete in middle layer of the high strength beam a sufficient difference in grade of concrete is taken.

1.1 Objective

- To understand the flexural behaviour of the high strength heterogeneous beam with varying thickness of lower grade of concrete in the neutral axis zone.
- To determine the optimum thickness of the middle layer of lower grade concrete.
- To study the crack pattern of an heterogeneous beam with normal beam designed to fail in flexure.

1.2 Scope of work

This research was carried out in order to find an alternative to existing method of concrete casting of beams with main aim of cost reduction without reducing its performance characteristics . The study is limited in comparing flexural behaviour of a high strength M70 RCC slender beam was compared with a heterogeneous beam, comprising of three layers top and bottom layer being M70 and middle layer of M20 normal grade concrete. The thickness of the middle layer is varied in accordance with the stress block parameters and tests were conducted to understand whether these heterogeneous beams show satisfactory strength characteristics. Also this research dealt in finding which composition of layers in the RCC beam showed an optimum flexural strength and how much reduction in quantity of materials it produced.

2. MATERIALS TEST

The constituent materials of reinforced cement concrete (RCC) are cement, fine and coarse aggregate, silica fumes, steel, water and superplasticizer. Basic tests were conducted on each of these materials.

Table -1: Properties of cement

Test	Result
Consistency(part 4)	29%
Specific gravity(part 11)	3.2
Initial Setting time(part 5)	40 minutes
Final setting time(part 5)	5 hours 30 minutes
Fineness (part 1)	9%
Soundness (part 3)	1mm
Compressive strength (part 6)	25N/mm² (3day) 35N/mm² (7 day)

Table 2: Properties of fine aggregates

Tests	Results
Specific Gravity	2.67
Sieve analysis	Zone 1 ; Fig 2
Fineness modulus	5.43

Table 3: Properties of coarse aggregate

Tests	Results
Specific Gravity	2.68
Water absorption, %	0.94
Bulk density, g/cm^3	1.5
Void ratio	0.79
Porosity	0.443
Sieve analysis	Fig 1
Fineness modulus	5.18

Bar Diameter mm	Average Diameter mm	Area (mm^2)	% Elongation	Yield Stress (N/mm^2)	Tensile Stress (N/mm^2)
8	8.1	51.529	8.84	495.4	617.8
10	9.8	75.738	6.67	502.6	668.6
20	20.1	317.309	8.56	543.6	778.6

Table 4:Properties of steel

3. EXPERIMENTAL PROGRAMME

3.1 Arrangement Of Different Grades Of Concrete In Beam

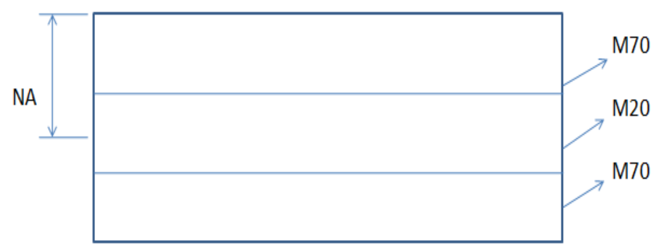

Fig -1: Layer arrangement

According to the figure 3.4 shown the heterogeneous beam will consist of three layers of concrete which will be comprising of total of two grades they are M70 and M20. Top layer will be M70 grade and the middle layer will be M20 grade and its thickness is taken from the neutral axis of the beam equidistant towards the top and bottom. The bottom layer is again M70 grade concrete. With the tests conducted on the basic materials those values are to be taken into consideration for determining the mix design for M20 and M70 grades and is discussed below.

3.2 Mix Design For M20 Grade Concrete

M20 grade :**Mix Ratio - 1 : 1.916 : 2.885**

For 1m3 of M 20 grade concrete:
Water content = 191 liters
Cement content = 380 kg/m3
Coarse Aggregate = 1096.65 kg=m3
Fine Aggregate = 728.37kg=m3
W/C ratio = 0.52

3.3 Mix Design For M70 Grade Concrete

This is done based on Erntroy and Shacklock method

M70 grade **Mix ratio**: **1:0.87:2.03**

Table 5: Cube compressive strength test for M70

Sl No	Silica fume %	S.P %	Water binder ratio	C.Strength 7days N/mm^2	C.Strength 28days N/mm^2
1	5	1.5	0.25	54.21	68.5
2	6	1.5	0.25	55.85	70.21
3	7	1.5	0.25	56.91	71.54
4	8	1.5	0.25	58.66	73.33
5	9	1.5	0.25	56.52	71.14

Fig -2: Compression test for cubes of M70 grade concrete in compression testing machine.

Thus silica fumes percent of eight is selected for the design mix.
For $1m^3$ concrete
Cement - 572.49 Kg/m^3
Water -145.26 Kg/m^3
F.A - 498.07 Kg/m^3
C.A - 1219.42Kg/m^3
Unit wt of concrete - 2491.79Kg/m^3
Silica fumes - 40.07Kg/m^3
Super plasticizer - 8.58Kg/m^3

3.4 Design Of Beam For Failure In Flexure

a= Shear span and d= effective depth
Slender beam (a/d)=2.7
Neutral Axes Xu= (.87fy.Ast)/(.36fckb) =81mm
Vu = Vc + Vs
Vs =(0 .87.fy.Asv .d)/ sv
Vc = Tc. (b.d)
Mu = 0.87.fy.Ast.(d – fy.Ast/b.fck
Moment (Mu) = Wu.a
Vu > Wu
Hence failure in flexure

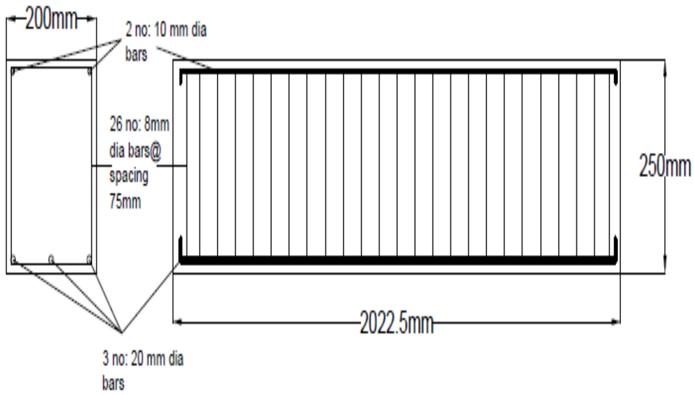

Fig -3: Reinforcement Details

3.5 Specimen details

6 beam specimens are designed and casted ensuring failure in flexure. The first one is a typical M70 high strength beam and the remaining 5 beams composition of layers are varied. This variation is done in reference with the stress block diagram.

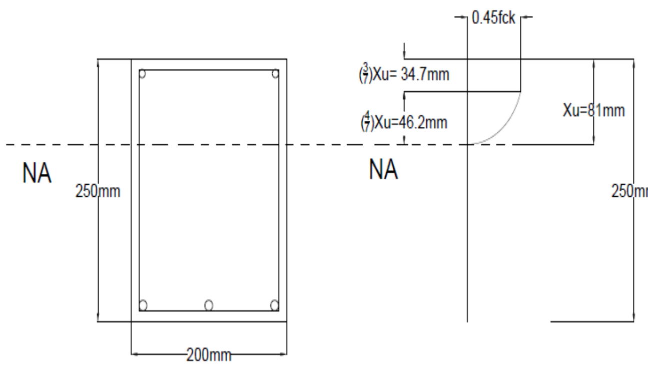

Fig -4: Stress block diagram

Table -6: Abbreviations for Specimens

Short form	Description
CB	M70 Control beam
T1	M70 + M20 thickness of 100mm with NA as centre
T2	M70 + M20 thickness of 90mm with NA as centre
T3	M70 + M20 thickness of 80mm with NA as centre
T4	M70 + M20 thickness of 60mm with NA as centre
T5	M70 + M20 thickness of 40mm with NA as centre

In this T1 beam has middle layer M20 above the parabolic curve in the stress block diagram and T2 beams have middle layer M20 at the parabolic and rectangular interface of stress block diagram. Remaining three has been varied to find out which thickness is best suitable. Steel reinforcement cage is ident0ical for all the specimens.

3.6 Casting And Testing Of Specimens

Plywood formwork of 2.0225m x 200mm x 250mm was made. Six identical steel reinforcement cage was made and placed.

Fig-5 Form work and reinforcement cage for three beams

For the five variety of specimens other than the control beam Each layer is casted After 28 days of curing the beam is taken to loading frame were two point loading is done to understand the flexural behaviour. Load deflection response are compared with the control beam specimen, Ductility factor and crack pattern are compared.

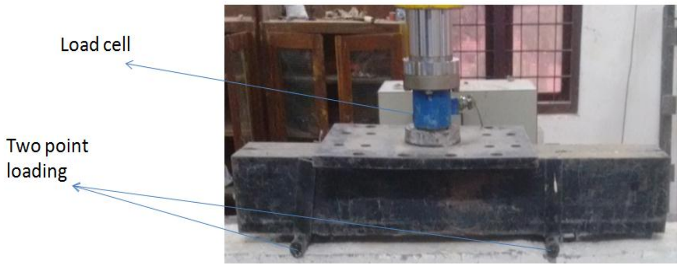

Fig-6: Two point loading of beams

4. RESULTS AND DISSCUSSIONS

4.1 First Crack And Ultimate Load

Table -7: Comparison of load carrying capacity of specimens

Specimen	First crack(KN)	Ultimate crack (KN)	% Variation	
			First crack	Ultimate crack
CB	145	320		
T1	110	280	-24.13	-12.5
T2	115	285	-20.68	-10.9
T3	140	315	-3.4	-1.56
T4	148	335	2.06	4.68
T5	135	305	-6.89	-4.68

From the above table it is understood that controlled beam (CB) , beams having middle layer thickness of 80mm, 60mm, 40mm ie (T3, T4 and T5) observed first crack after the designed flexural failure load of 128KN ie (Wu). While beams having middle layer thickness of 100mm and 90mm (T1 and T2) observed first crack before the flexural failure load. Thus can be understood that the design calculations for T1 and T2 beams must be changed because they lie very much near to the rectangular portion of the stress block diagram. Now comparing the percentage variation of load at first crack and ultimate crack between the controlled beam and the other beams it is found out that for T1 suffered a decrease of 24.13% and 12.5 % while T2 suffered a decrease of 20.68% and 10.9%. So both variations can be understood to perform worse than the controlled beam specimen. T5 beam also showed a decrease of 6.89% and 4.68%. Considering T3 and T4, T3 also showed a decrease of 3.4% and 1.56% but these values are permissible taking into account the margin of error and T4 showed an increase of 2.06% and 4.68% which is commendable and thus T4 beam having middle layer thickness of 60mm is the better choice from the results obtained from above.

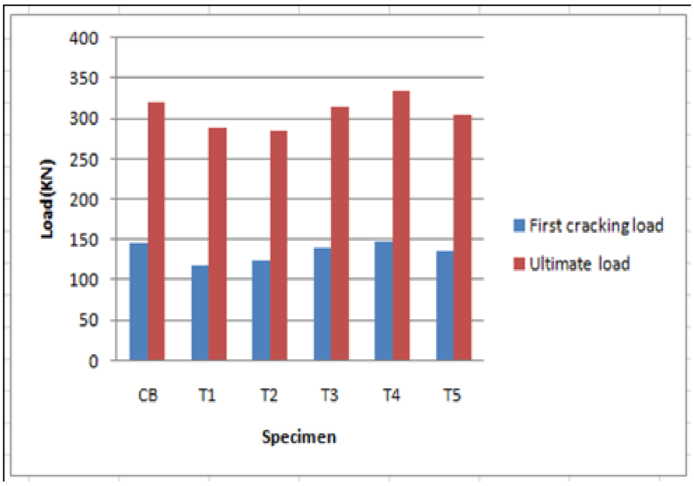

Chart-1: Comparison of load capacity

4.2 Crack Pattern

Fig-7 : Crack pattern for Control beam (CB)

Fig-8 Crack pattern for beam having middle layer of thickness 100mm (T1)

Fig-9 Crack pattern for beam having middle layer of thickness 90mm (T2)

Horizontal splitting of the compressive zone was observed for T1 and T2 beams which occurs independently from any web crack. Such splitting may be due to the development of tensile stresses within the compressive zone associated with loss of bond between concrete and flexural steel. (Kotsovos, 2014).

Fig-10 Crack pattern for beam having 80mm middle layer thickness (T3)

Fig-11 Crack pattern for beam having 60mm middle layer thickness (T4)

Fig-12 Crack pattern for beam having middle layer thickness of 40mm (T5)

Proper crack pattern for beam designed for flexural failure was observed for the remaining specimens such as T3,T4 and T5.

4.3 Load Deflection Graphs

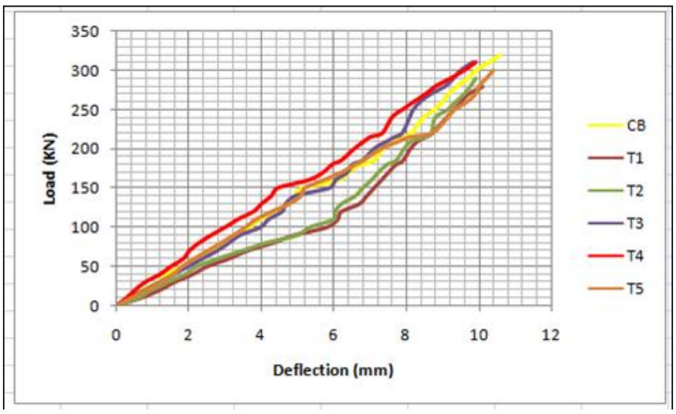

Chart-2: Load deflection response comparison of all specimens.

T1 and T2 beams performed the worse compared to the other specimens. CB,T3 and T5 beams have shown a similar curve and thus it can be said it has shown similar load deflection response characteristics. It is obtained from the comparison that T4 beam shows comparatively lesser deflection than the other specimens for the same load applied on it.

4.4 Ductility Factor

The ultimate load deflection and yield load deflection obtained from the load deflection graphs are used to find the ductility ratio. Ductility factor is the ratio between Ultimate load deflection and Yield load deflection. It is a measure of strength of the beam. Higher the value of the factor for a beam higher is strength of beam.

Table -8: Comparison of Ductility factor

Specimen	Ultimate Deflection(mm)	Yielding Deflection (KN)	Ductility Factor
CB	10.58	5.1	2.079
T1	10.1	6.2	1.629
T2	9.9	6.05	1.633
T3	9.8	4.8	2.041
T4	10.28	4.4	2.336
T5	10.41	5.1	2.045

5. CONCLUSIONS

From this experimental study the following conclusions were drawn

- The crack pattern obtained for flexural behavioral of all the R.C.C Specimens with M70-M20 combination were comparable with crack pattern of control beam.
- Horizontal splitting of the compressive zone was observed for T1 and T2 beams. This splitting may be due to the development of tensile stresses within the compressive zone associated with loss of bond between concrete and flexural steel.
- For T1, T2, T3 and T5 beams there was a decrease in ultimate load carrying capacity by 12.5 %, 10.9%, 1.56% and 4.68% compared to controlled beam while T4 beam showed an increase of 4.6% than Controlled beam.
- This odd behaviour shown by T1 and T2 may be due to the fact that M20 grade concrete was laid up to a height of 3.8mm above the interface of parabolic and rectangular portion of stress block diagram for T1 beam and 1.2mm below the interface for T2 beam.
- Ductility ratio obtained for T4 was 12.36 % higher than controlled beam, performing better than the other four variation of specimens(T1,T2,T3,T5)
- Thus the beam having M20 grade concrete laid upto a height of 16.2mm below the interface of rectangular and parabolic portion of stress block diagram ie (46.2�30=16.2mm) and M20 thickness of 30+30=60mm is the optimum thickness.
- The heterogeneous beam are cost effective when compared to control beam.
- The optimum case T4 beam lead to a reduction of 25% in cement, 18% in coarse aggregate, 36.9% in silica fume so this method can be adopted for multi-storied buildings which helps in the reduction of overall cost of the project without having to sacrifice in its structural strength.

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