BEHAVIOR OF CONCRETE GRADE VARIATION IN TENSION AND COMPRESSION ZONES OF RCC BEAMS

B S Karthik[1], Dr.H.Eramma[2]& Madhukaran[3]

[1]PG Student, M.Tech CADS, [2]Associate Professor, [3]Assistant Professor,

Department of Studies in Civil Engineering,

University BDT College of Engineering, Davangere, 577004 Karnataka, (India)

ABSTRACT

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, viz. compression zone at top and tension zone at bottom. As concrete is weak in tension, steel is introduced in the tension zone to take the tension, but as strength of concrete is ignored in tension zone with respect to compression zone. So logically no concrete is required in tension side. But 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 tensions more than strain transferring, then why to go for same grade of concrete which is used in upper zone? This is basic question which led to the idea of concrete grade reductioning tension zone for RCC beams to reduce construction cost.

Keywords: M_{20}, M_{25}, Behavior of Partial Beam & Normal Beam, Flexural Member

I INTRODUCTION

In the ancient time size of walls are 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 IS456-1978, M15 grade of concrete was also permitted to be use in general construction but according to new revision made in IS 456-2000, lowest grade of concrete which can be used in concreting for construction is M20 for mild environment. With the help of creative sense, imagination, understanding and keen observation of structures in nature, 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 finding viz. reduction in the thickness of wall, reduction in the Beam-column sizes etc. But no research or study has been made until now on replacement of sacrificial concrete in case of deep beams. This is also a research area in structural design.

As concrete is weak in tension, to take this tension steel reinforcement is provided at the bottom side of the beam section. As compressive stresses are induced in the zone above the neutral axis, compressive strength of the concrete lying above neutral axis is very important parameter. This induces compressive force in the top zone at a distance of 0.42 X_U. (X_U –Neutral axis distance from top of section).

The tension force acts at centroid of steel reinforcement provided at bottom of section. 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.

Generally being a structural engineer we should concentrate towards the structural as well as functional design of the structure. But while designing, economy of the project is also a major factor. Keeping economy and safety of the structure in mind, we came with the concept of "Partial Beam".

A partial beam is a normal beam cast with two grades 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 work

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 M_{25} and M_{20} grade of concrete are shown in Table 1 and Table 2.

Table 1: Mix Design Proportion for M_{25}

Water	Cement	FA	CA	
197.16	394.32	1121.58	679.725	by mass
0.50	1	1.72	2.84	Absolutevolume

Table 2: Mix Design Proportion for M_{20}

Water	Cement	FA	CA	
197.16	358.47	1121.472	708.981	by mass
0.55	1	1.97	3.12	Absolutevolume

2.2 Test Setup

In the present investigation, tests were conducted on 12 beam specimens of 150 mmx150 mm x 700 mm cast in moulds. The reinforcement used is 2 Nos. of 10mm diameter bar for all the beams. Separate mix design was prepared for M_{25} grade of concrete (1: 1.72: 2.84). The formwork prepared and ingredients are weighed accurately with weight balance. Ingredients are mixed with the help of concrete mixer. Concrete was placed in the formworkin layers of approximately 60 mm and compacted. Similarly, the layers were successively placed one above the other and compacted. End faces were properly compacted to get smooth finish. The beam specimens were stripped from their moulds after 24 hours and submerged in water tank for 28 days for curing after casting. For composite beams separate mix design was prepared for M_{25} grade of concrete (1:1.72:2.84) and M_{20} grade of concrete (1:1.97: 3.12). Neutral axis is marked with the help of a chalk piece between two end plates. Concrete in the tension zone was placed in the formwork in layers of approximately 60mm and compacted firstly for M_{20} grade of concrete. Similarly, the layers were successively placed one above the other and compacted. After the level of chalk piece mark was reached, the concreting operation was stopped with M20 grade of concrete.All the twelve beams were tested in a Universal Testing Machine (U.T.M) of capacity 100 ton available in the machine lab. During testing, the beams were preloaded with a minimal force of 0.5 kN to allow initiation of the dial gauges. The developments of cracks were observed and crack width was measured at the level of tensile reinforcement using a hand-held microscope with sensitivity of 0.02 mm. All strain, crack width and deflection measurements were measured at every load increment. The first crack load was noted immediately after its formation and all the cracks were marked as and when they propagated in the beam.

Fig 1: Marking of Neutral Axis

All the twelve beams were tested in a Universal Testing Machine (U.T.M) ofcapacity 100 ton available in the machine lab. During testing, the beams were preloaded with a minimal force of 0.5 kN to allow initiation of the dial gauges.

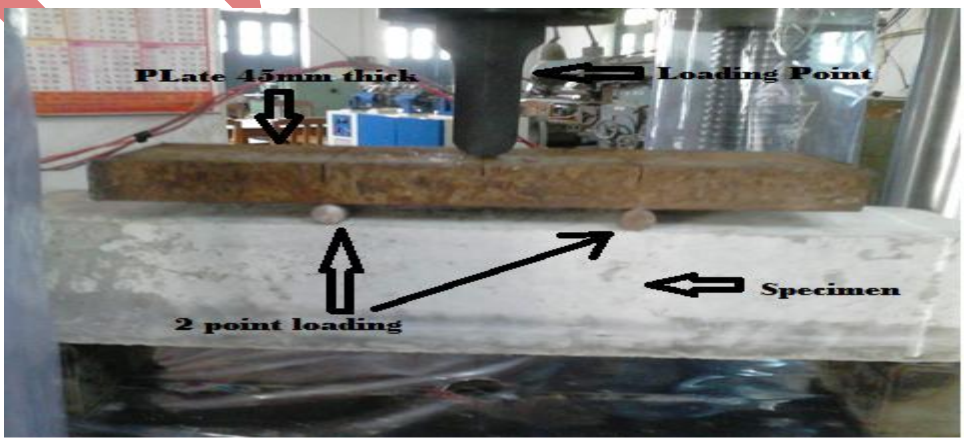


Fig 2: Test Setup

The developments of cracks were observed and crack width was measured at the level of tensile reinforcement using a hand-held microscope with sensitivity of 0.02 mm. All strain, crack width and deflection measurements were measured at every load increment. The first crack load was noted immediately after its formation and all the cracks were marked as and when they propagated in the beam

872.3 Design of RCC Beam - According to IS 456-2000

DataOverall Depth (D) = 150mm

Width of beam (b) = 150mm

Clear cover =20mm

Effective cover (d') =25mm

Effective depth (d) = 125mm

Characteristic strength of concrete (fck) =25 N/mm^2

Characteristic strength of steel (fy) = 500 N/mm^2

Span = 700mm

Dia of Bar = 10mm

According to IS 456-2000

Pt]limit = 0.96%

100Ast /b*d =0.96%

Ast = 0.96*150*125/100

Ast = 180 mm^2

Area of steel Provided =2*(π*10^2 /4) =157.06 mm^2

Hence section is under reinforced **Depth of Neutral axis**

Xu = 0.87*fy*Ast/0.36*fck*b

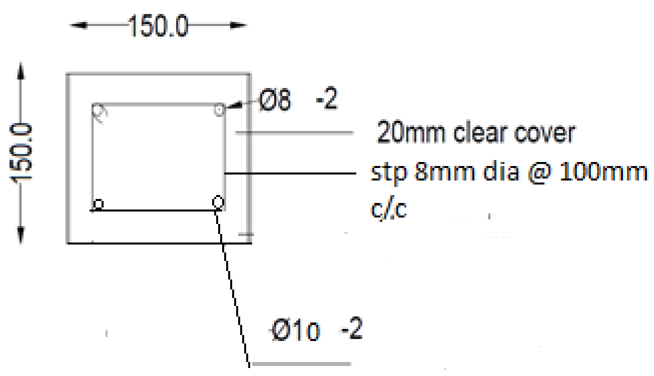
Xu = 0.87*500*157.06/0.36*25*150

Xu = 50.61

Limiting Value of the Depth of Neutral axis

Xumax = 0.46 *150 = 57.5(Xu < Xumax)

Hence section is under reinforced



Moment of Resistance

Mu lim = 0.87*fy*Ast*(d-0.42Xu)

=0.87*500*157.06*(150-0.42*63.26)

=70.8Kn-m\

III.TESTRESULTS

The results of the test conducted on twelve RCC beams have been discussed in this chapter. The discussion is based on the load at failure, cracks pattern, load deflection curves, stress strain curves and stress displacement of each beam. The twelve beams chosen in the current experimental program were aimed to achieve many objectives through a comparison between the behaviors of these beams. The testing beam M_{20} Grade of concrete and M_{25} Grade of concrete revealed the behavior of partial beam.

The Partial beam is a normal beam cast with two grades concrete, one above and other below the neutral axis. This has been achieved comparing the behavior of those beams M_{20}& M_{25} to Partial beam. Such behavior of all tested beams has been presented in the following sections. Necessary comparison will be made between different beams in order to achieve the objectives of the present experimental study.

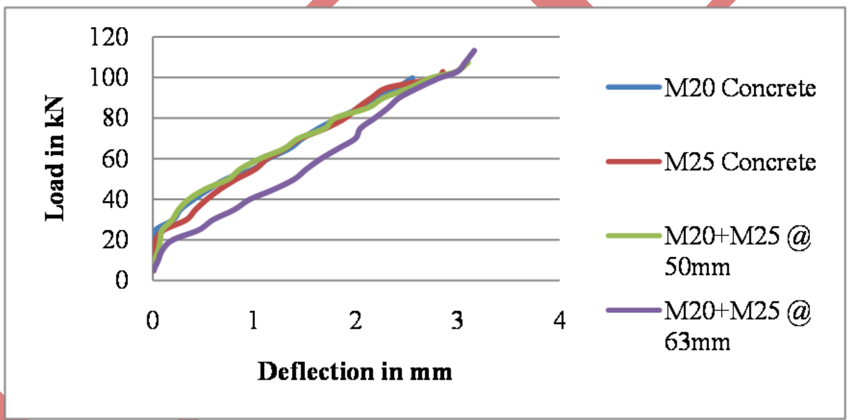


Fig3: Load-Deflection Curve for All Beams

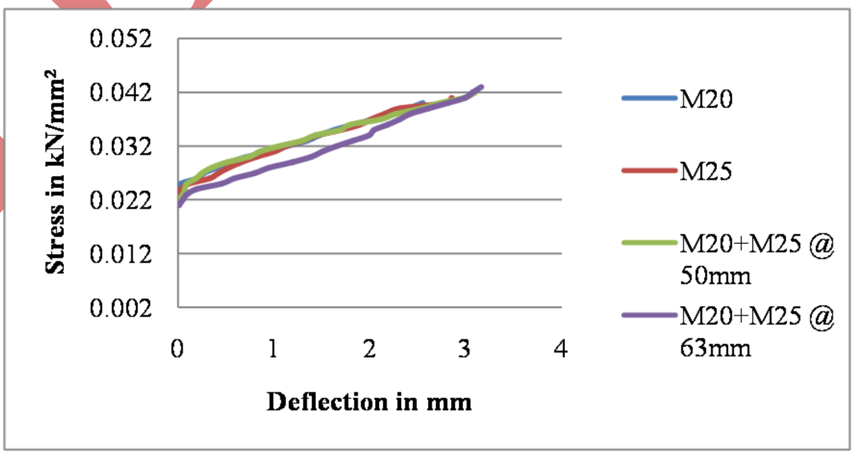


Fig4: Stress-Deflection Curve for All Beams

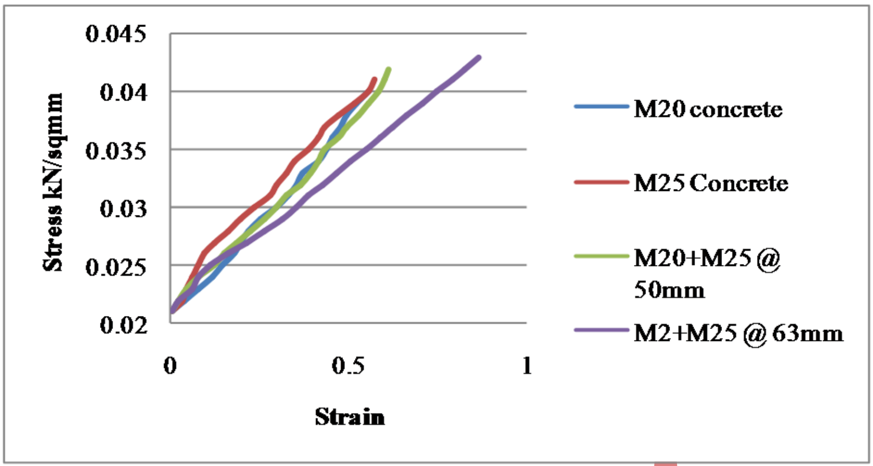


Fig5: Stress-Strain Curves for All Beams

3.1 Ultimate Moments

A comparison between the experimental ultimate moments (Mult) and the theoretical design moments are shown in Table 7.16. The theoretical design moments (Mdes) of the beams was predicted using the parabolic rectangular stress block analysis are recommended by IS 456-2000. For slag beams, the ultimate moment obtained from the experiments was approximately 28% to 40% higher compared to predicted values. From the performed tests, it was observed that for steel slag concrete beams, IS 456 can be used to obtain a conservative estimate of the ultimate moment capacity and also adequate load factor against failure.

Table 3: Comparison between Experimental and Theoretical Ultimate Moment

Beam No.	Experimental Ultimate moment(kN m)	Theoretical design moment (kN m)	% Increases
M_{20}	9.96	7.08	28.91
M_{25}	10.2	6.72	34.11
M_{20}+M_{25}@50mm	10.73	7.08	34.01
M_{20}+M_{25}@63mm	11.32	6.72	40.63

3.2 Deflection Behavior

Figures 3 show the typical experimental load deflection curves for steel slag concrete beams. In all beams, before cracking occurred, the slope of the load deflection curved was steep and closely linear. Onceflexural cracks formed, a change of slope of the load deflection curve was observed and this slope remained fairly linear until yielding of the steel reinforcement took place.

Table 4 compares the predicted midspan deflection under service moments with the experimental values. The predicted deflection is calculated from load values according to the strength of materials equation, using the formula

$$\Delta = \frac{5Wl^3}{163EI}$$

Where, Δ = Midspan deflection in mm,

W = Load acting on the beam in kN

l = Effective span of the beam in mm and

EI = Flexural rigidity in N/mm2.

Table 4: Deflection of Concrete Beams at Service Load Moments

Beam No.	Deflectionformexperiment Δexp (mm)	Theoreticaldeflection Δthe (mm)	% Increases
M_{20}	2.55	1.11	56.47
M_{25}	2.85	1.14	60
M_{20}+M_{25}@50mm	3.1	1.19	61.61
M_{20}+M_{25}@63mm	3.16	1.26	60.12

It was observed that the deflection obtained from the experiment at the service moments compares reasonably well to the predicted deflection. IS 456 recommends an upper limit of span/250 for the deflection in order to satisfy the appearance and safety criteria of a structure.

From the load deflection graph it is observed that the beams beam behave similar to conventional R.C.C beams particularly the beam specimens with normal concrete have no ductile failure the failing in compression remaining all specimens are failure in shear failure. Hence it is also observed that the grade of concrete and reinforcement ratio and spacing of stirrups have certain effects on the flexural behavior of reinforced concrete beam.

3.3 Ductility of Beams

Table 5: Ductility Ratio

Beam specimen	Yield deflection	Ultimate deflection	Ductility ratio
M_{20}	2.19	2.55	1.16
M_{25}	2.27	2.85	1.25
M_{20}+M_{25} @ 50mm	2.44	3.1	1.27
M_{20}+M_{25} @ 63mm	2.85	3.16	1.10

Load carrying capacity until total failure. In reinforced concrete beam the deformation most suited for measurement of ductility is the curvature of the beam. Alternatively here the deflection is used to measure the ductility. Ductility ratio, μ = Δu/Δy Where, Δu- Maximum deflection occurred at failure stage. Δy- deflection occurred at member yields. Ductility behavior of the test specimens are shown in Table 3. From the ductility ratio calculation, it is foundDuctility is the ability of the member to sustain deformation beyond the elastic limit while maintaining the reasonable d that the ductility of Partial Beams are similar to the conventional beams, according to code it is permissible and can be considered for structural member subjected to large displacements, due to sudden force caused by earthquake.

3.4 Cracking Patterns and Failure Modes

Crack widths were measured at every load interval at the tension steel level and thecrack formations were marked on the beam. The initial cracks were occurred at about 15% to 30% of the ultimate load. It was noticed that first crack always appeared close to the midspan of the beam. The cracks formed on the surface of the beams were mostly vertical, suggesting failure in flexure.

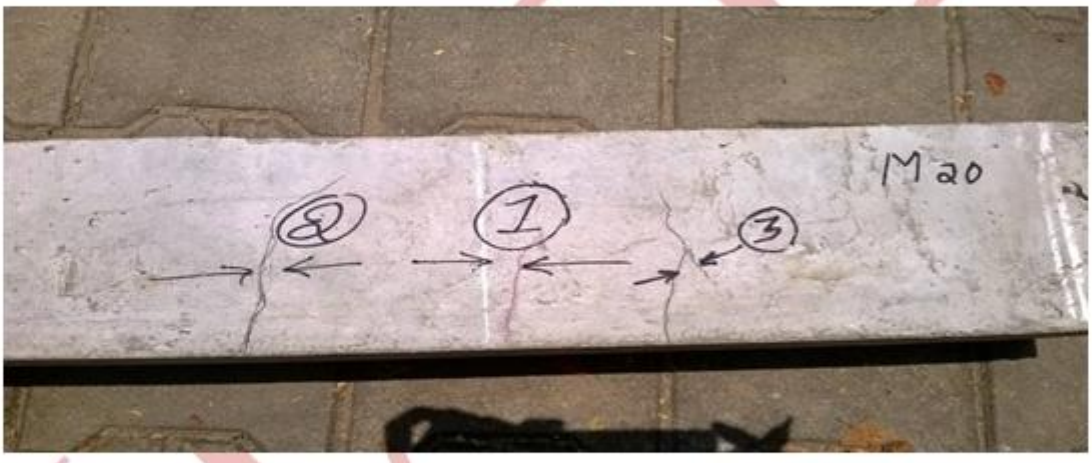


Fig 6: Cracking Pattern for the M_{20} Grade Concrete

For the M_{20} grade concrete, the first crack is observed at the mid span at a load of 27.2kN and the beam failed in a flexural mode at a load of 99.650kN.

Fig 7: Cracking Pattern for the M_{25} Grade Concrete

For the M_{25} grade concrete Beam the first crack is observed at the mid span at a load of 35.64kN and the beam failed in a flexural mode at a load of 102.80kN.

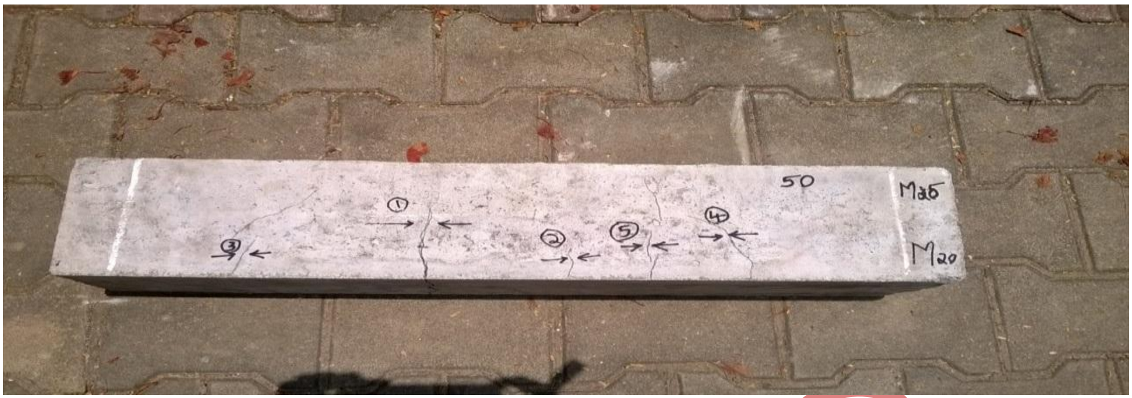


Fig 8: Cracking Pattern for the M_{20}+M_{25} @ 50mm

For the M_{20}+M_{25} @ 50mm Beam the first crack is observed at the mid span at a load of 47.85kN and the beam failed in a flexural mode at a load of 107.35kN.

Fig 9: Cracking Pattern for the M_{20}+M_{25} @ 63 Mm

For the M_{20}+M_{25} @ 63mm Beam the first crack is observed at the mid span at a load of 64.33 kN and the beam failed in a shear mode at a load of 113.250 kN.

V. CONCLUSION

Based on the investigations, the following conclusions were drawn.

- All Partial beams showed typical structural behavior in flexure. The overall flexuralbehavior of Partial beam used in this study closely resembles that of equivalent beammade with Normal beam.
- The experimental ultimate moment gives a conservative estimate for Partial beams for28% to 40% of a theoretical ultimate moment.
- Deflection of Partial beam calculated using Equation under service loadscan be used to give reasonable predictions. The deflection under the service loads forbeams were within the allowable limit provided by IS 456(2000).Partial beams showed good ductility behavior. All the beams exhibited considerableamount of deflection, which gives enough warning before failure.
- The crack width at service loads varies from 0.10 mm to 0.3 mm and this was withinthe maximum allowable limits.

- As the depth of higher grade concrete increases in compression zone, resistance tofirst crack development also increases.
- All type of beams have shown flexural failure, no shear cracks were seen. It may besmall span of the test specimen
- Crack patterns and their developing system, failure mode and the sustainability leadsto select the Partial Beams as safer and serviceable than the Normal Beams.
- It suggests that the $M_{20}+M_{25}$ @ 63mm Neutral axis can be considered as optimumcontent of Partial beam.
- From the overall study, it can be concluded that Partial beam is more efficient andeconomical than normal RCC beam, this is considered as best strengthening RCCbeam among all the process.
- It is concluded that, Partial beam is a beautiful result of the application of engineeringin building construction works to achieve economy as well as reduction in theenvironmental impact due to construction works

VI. ACKNOWLEDGEMENTS

The authors wish to thank the authorities of Visvesvaraya Technological University, Belgaum for giving an opportunity to conduct the experiments in the Concrete and Highway Engineering Laboratory of University BDT College of Engineering Davangere. 577004.

REFERENCES

Journal Papers:

[1] Arivalagan. S – *"Moment Capacity, Cracking Behavior And Ductile Properties Of Reinforced Concrete Beams Using Steel Slag As A Coarse Aggregate"* Volume 12 Issue 2 Version 1.0.

[2]Arivalagan.S–*"Experimental Study on the Flexural Behavior of Reinforced Concrete Beams as Replacement of Copper Slag as Fine Aggregate"* Volume 3, Issue 4: pg-176-182.

[3]D. Brindha and S. Nagan–*"Utilization of Copper Slag as a Partial Replacement of Fine Aggregate in Concrete"*Vol. 03, No. 04.

[4]Dattatreya J K,Rajamane N P,Sabitha D, Ambily P S, Nataraja M C– *"Flexural behavior of reinforced Geopolymer concrete beams"* volume 2, no 1.

[5]A.S.Jeyabharathy[1], Dr.S.Robert Ravi[2] (2013) - "*Experimental Investigation on Behavior of R.C.C Beam Retrofitted with Sisal Fibre Sheet*" vol. 2, issue 7.

[6]P.S.Joanna[1], Jessy Rooby[2], Angeline Prabhavathy[3], R.Preetha[4], C.Sivathanu pillai[5](2013)-*"Behavior of Reinforced concrete beams with 50 percentage fly ash"* volume 4, issue 2.

Books:

[7] Neville, A.M. Properties of concrete, Pitman Publishing Ltd., London, (1995).

[8] M.S.Shetty, "Concrete Technology" Chand Publishers (2011).

[9] Dr. M. C. Nataraja. "Concrete mix design"