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Effects of 16mm Size Coarse aggregate on Flexural Strength of Reinforced Concrete Beam

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ABSTRACT

These studies on reinforced concrete members have shown that there is loss of flexural strength of reinforced concrete beam casting with specific size of aggregate. This is because; there are voids found inside the concrete mass and the redistribution of bending moment which considerably affects the behavior of the bending stress. This paper gives the approach forward on the effects of uniform graded aggregate of specific fraction on flexural strength of a beam. Concrete cubes and beams were shaped in accordance with BS 1881-108 (1983) and ASTM C293 with a single fraction aggregate size of 16mm,by using a standard mould of internal dimension 150 x 150 x 150 for the concrete cubes and a mould of internal dimension of 100 x 150 x 750mm for the reinforced concrete beam. Flexural test results generated on 6 reinforced concrete beams to evaluate the implication of using 16mm coarse aggregate are reported. Test parameters considered include concrete compressive strength, ratios of tensile and compressive reinforcements, and spacing of lateral ties. The water cement ratio was kept at 0.60 with a mix proportion of 1:1.5:3. The specimen produced were all subjected to curing in water for 28 days and were all tested to determine the compressive strength and flexural strength using Compressive Testing Machine. Compressive strength of cubes is 28.41N/mm^2, for coarse aggregate sizes 16mm.

That of flexural strength of test beams is 7.93N/mm^2.

Key words: Flexural strength, compressive strength, stiffness, specific fraction, aggregate size.

1. Introduction

Concrete elements deflect, crack, and loose its stiffness when subjected to external load. Loss of flexural strength of concrete is largely responsible for the formation of cracks in structure. In reinforced concrete structures, the mix proportions of the materials of the concrete and aggregate type moderately determine the compressive strength while the composite action of concrete and steel reinforcement affords the flexural strength. In occasion of loss of stiffness, steel reinforcement no longer supports flexural stresses; concrete in turn is subjected to flexure. The compressive strength and flexural strength therefore play a important role. Effect of coarse aggregate size on the flexural and compressive strengths of concrete beam was investigated.

2. Literature review

2.1 Reinforced concrete material properties

The rise in temperature affects the strength and modulus of elasticity of both concrete and steel reinforcement.However, the rate at which the strength and modulus of elasticity decrease depends on the rate of increase in the temperature, duration of the fire and the insulating properties of concrete.

2.1 Water

Water used was for following purposes of different works:

2.1.1 Mixing water

The mixing water that is the free water used in freshly mixed concrete has three main functions

i.e. it reacts with cement binder and thus producing hydration, it acts as a lubricant contributing to the workability of the fresh mixture and it confined necessary space in the paste for the hydration process and also waters containing no more impurities than 2000 ppm of common ions (that is, 0.2% of the weight of water) are generally acceptable as mixing waters.In this work, water used is fresh with approximately 1800 ppm.

2.1.2 Water for curing

Water for curing are less stringent than mixing mainly because, curing water is in contact with the contact with the concrete for relatively short time. Such water may contain more inorganic and organic materials, sulfuric an hydride, acids, chlorides, and so on, than acceptable mixing water; especially discoloration of the concrete surface is not objectionable. Nevertheless, the permissible.

2.1.3 Water for washing aggregate

Water for washing aggregate should not contain materials in quantities large enough to produce harmful films or on the surface of aggregate.

3. Cement content

For an equivalent grade the assurance of minimum cement content was used and batched by weight to comply with the specified minimum cement content if the compressive strength results for the equivalent grade are to comply with the requirements of clause 3.1.6.2. of BS5328 Part 4:1990 The samples were heated at varying temperatures of 250°C, 600°C and 750°C for one hour and two hours intervals.

4. Aggregates

Aggregates used in this work were crushed, processed natural materials as specified in BS 882 1992. The course aggregates used constituted of only16mm aggregates retained on a 16 mm BS410 test sieve and Containing no finer materials.

Fine aggregates were uncrushed river sand determined in accordance with BS 812-103.1using 0.6 mm sieve determined by sieve analysis test. The amount of material passing the 75µm sieve controlled at 4%.Water absorption was determined in accordance with BS 882.

5. Fine Aggregate (Sand)

Locally available sand, is used as fine aggregate, it confirms to zone II of IS 383-1983 and other necessary properties are given in table.

Table: 3.2 Physical Properties of Fine Aggregates (Sand)

Sr. No	Property	Results
1	Particle Shape	Size Round 4.75 mm down
2	Fineness Modulus	3.17
3	Silt Content	2 %
4	Specific Gravity	2.60
5	Bulk Density	1783 kg/m^3
6	Surface Moisture	Nil

6. Coarse Aggregate

Locally available crushed stone aggregates with size of 16 mm are used. The test results are as follows:

Table: 3.3 Physical Properties of coarse Aggregate

Sr No	Property	Results
1	Particle Shape Size	Angular 16mm
2	Fineness Modulus of 16 mm aggregates	6.8
3	Specific Gravity	2.765
4	Water Absorption	1.04%
5	Bulk density of 20mm aggregates	1603 k/mm3
6	Surface moisture	Nil

7. Workability

Workability was controlled within the following limits:

7.1 Slump

In accordance with BS1881 part 101 the slump was controlled at 60% Water cement ratio120mm

7.2 Compacting factor

Targeted at 0.93

DETAILS OF SLUMP & COMPACTION FACTOR

S. No.	w/c Ratio	SLUMP (mm)	Compaction Factor
	0.50	120	0.93

8. APPLICATION ON FLEXURAL STRENGTH DESIGN OF RC BEAMS

Test Set Up The flexure strength of the concrete is determined according to Indian Standard 516:1959. The beam is 800 mm long, with a cross-section of 100mm x 150mm. The bottom reinforcement of the beam is 2-10 mm diameter and 2- 8 mm diameter bars are provided at top, while 8 mm diameter stirrups @ 110 mm c/c are provided. Conceptual two point load loading pattern and support condition for the beam.

A series of design charts is produced for flexural strength design of doubly-reinforced beams with compression steel ratio of 2%, concrete strengths from 40 to 100 MPa and tension steel ratios from 0 to 4%.

- b = 100 mm
- h = 150 mm
- d = 125 mm
- $d1$ = 25 mm
- fy = 415 MPa
- Es = 200,000 MPa
- fc' = 30 to 100 MPa
- $\rho t = Ast / bd$ = 1 to 4%
- $\rho c = Asc / bd$ = 0 to 2%

PROCEDURE OVERVIEW

This test method covers the determination of the flexural strength of concrete by the use of a simple beam with third-point loading. A simply supported concrete prism is loaded by two point loads placed at third points along the span. The load is monotonically increased until flexural failure occurs. Based on the peak load, the peak flexural stress within the prism is calculated. ASTM C78 (Ref. 7.1) formed the basis for the development of this procedure. This method is commonly referred to as the modulus of rupture.

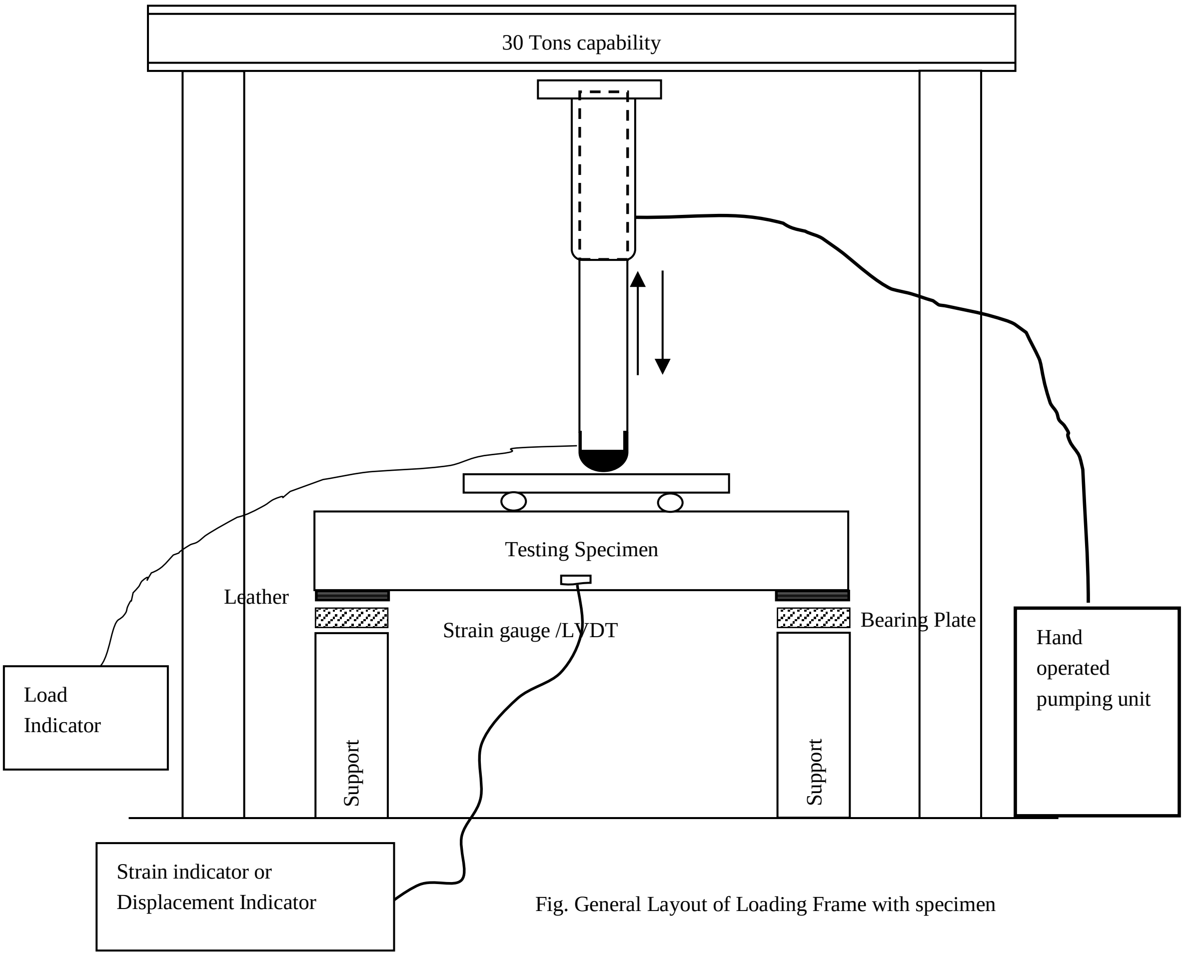
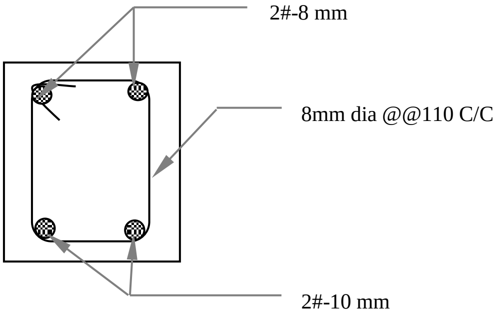


Fig. General Layout of Loading Frame with specimen



Beam -1 with pure 16mm coarse aggregate

Beam -1 with pure 16mm coarse aggregate

Normal Concrete: Flexural Strength of normal beam

NB1

S. No	Load (t)	Load (N)	Length (mm)	Moment of Inertia (mm^4)	Deflection (mm)	Bending moment M=(WL/3)	Bending stress (N/mm^2)
1	0	0	750	28125000	0.00	0	0.00
2	2.8	28000	750	28125000	0.20	7000000	18.67
3	4	40000	750	28125000	0.30	10000000	26.67
4	5.7	57000	750	28125000	0.40	14250000	38.00
5	7.1	71000	750	28125000	0.50	17750000	47.33
6	8.2	82000	750	28125000	0.60	20500000	54.67
7	8.3	83000	750	28125000	0.70	20750000	55.33
8	8.5	85000	750	28125000	0.80	21250000	56.67
9	8.7	87000	750	28125000	0.90	21750000	58.00
10	8.4	84000	750	28125000	1.10	21000000	56.00
11	8.7	87000	750	28125000	1.20	21750000	58.00
12	8.9	89000	750	28125000	1.30	22250000	59.33
13	8.8	88000	750	28125000	1.40	22000000	58.67
14	8.9	89000	750	28125000	1.50	22250000	59.33
15	8.9	89000	750	28125000	1.60	22250000	59.33
16	9.2	92000	750	28125000	1.80	23000000	61.33
17	9	90000	750	28125000	1.90	22500000	60.00

Normal Beam
NB2

S. No	Load (t)	Load (N)	Length (mm)	Moment of Inertia (mm^4)	Deflection (mm)	Bending moment M=(WL/3)	Bending stress (N/mm^2)
1	0.1	1000	750	28125000	0.00	250000	0.67
2	0.5	5000	750	28125000	0.10	1250000	3.33
3	2.4	24000	750	28125000	0.20	6000000	16.00
4	5	50000	750	28125000	0.30	12500000	33.33
5	6.7	67000	750	28125000	0.40	16750000	44.67
6	6.7	67000	750	28125000	0.40	16750000	44.67
7	6.7	67000	750	28125000	0.40	16750000	44.67
8	6.7	67000	750	28125000	0.40	16750000	44.67
9	7.4	74000	750	28125000	0.50	18500000	49.33
10	7.6	76000	750	28125000	0.50	19000000	50.67
11	7.6	76000	750	28125000	0.60	19000000	50.67
12	7.6	76000	750	28125000	0.70	19000000	50.67
13	7.6	76000	750	28125000	0.80	19000000	50.67
14	7.7	77000	750	28125000	0.90	19250000	51.33
15	7.4	74000	750	28125000	1.00	18500000	49.33
16	7.4	74000	750	28125000	1.10	18500000	49.33
17	7.4	74000	750	28125000	1.20	18500000	49.33

Normal Beam
NB3

S. No	Load (t)	Load (N)	Length (mm)	Moment of Inertia (mm^4)	Deflection (mm)	Bending moment M=(WL/3)	Bending stress (N/mm^2)
1	0	0	750	28125000	0.00	0	0.00
2	1.3	1300	750	28125000	0.10	325000	0.87
3	2.1	2100	750	28125000	0.10	525000	1.40
4	2.3	2300	750	28125000	0.10	575000	1.53
5	2.5	2500	750	28125000	0.10	625000	1.67
6	2.9	2900	750	28125000	0.10	725000	1.93
7	3.1	3100	750	28125000	0.20	775000	2.07
8	3.2	3200	750	28125000	0.20	800000	2.13
9	3.3	3300	750	28125000	0.30	825000	2.20
10	3.6	3600	750	28125000	0.30	900000	2.40
11	3.7	3700	750	28125000	0.40	925000	2.47
12	4.2	4200	750	28125000	0.50	1050000	2.80
13	4.9	4900	750	28125000	0.60	1225000	3.27
14	5.2	5200	750	28125000	0.70	1300000	3.47
15	5.5	5500	750	28125000	0.80	1375000	3.67
16	6.1	6100	750	28125000	0.90	1525000	4.07
17	6.3	6300	750	28125000	1.00	1575000	4.20
18	6.8	6800	750	28125000	1.10	1700000	4.53
19	7.6	7600	750	28125000	1.20	1900000	5.07

20	7.3	7300	750	28125000	1.30	1825000	4.87
21	7.4	7400	750	28125000	1.40	1850000	4.93
22	7.7	7700	750	28125000	1.50	1925000	5.13
23	7.9	7900	750	28125000	1.60	1975000	5.27
24	8	8000	750	28125000	1.70	2000000	5.33
25	8.1	8100	750	28125000	1.80	2025000	5.40
26	8.3	8300	750	28125000	1.90	2075000	5.53
27	8.2	8200	750	28125000	2.00	2050000	5.47
28	8.4	8400	750	28125000	2.20	2100000	5.60
29	4.8	4800	750	28125000	3.70	1200000	3.20

Beam -1 with pure 16mm coarse aggregate

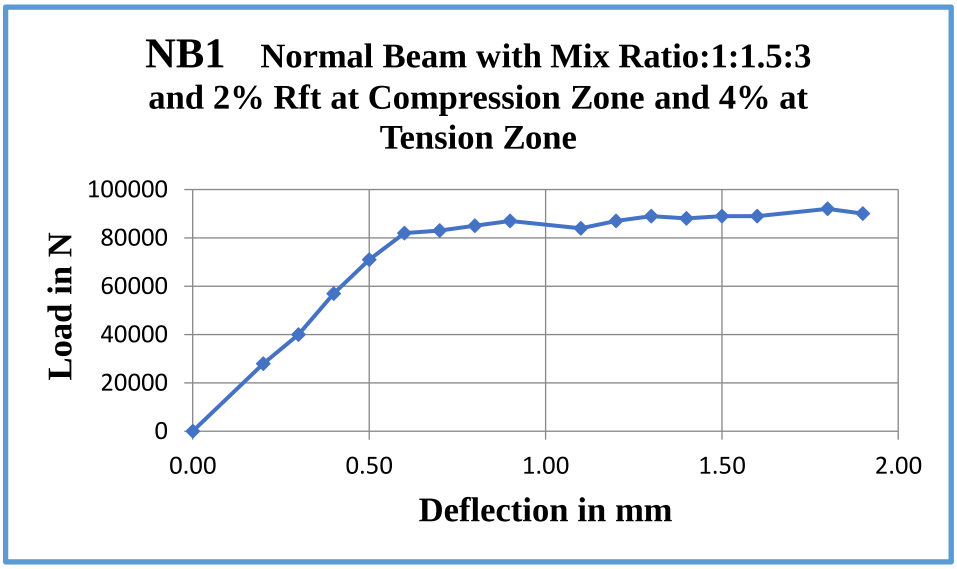
S. No	Load (t)	Load (N)	Length (mm)	Moment of Inertia (mm^4)	Deflection (mm)	Bending moment M=(WL/3)	Bending stress (N/mm^2)
1	1.5	15000	750	28125000	0.8	3750000	10.00
2	1.8	18000	750	28125000	1.1	4500000	12.00
3	2.3	23000	750	28125000	1.3	5750000	15.33
4	2.8	28000	750	28125000	1.5	7000000	18.67
5	3.3	33000	750	28125000	1.8	8250000	22.00
6	3.6	36000	750	28125000	1.9	9000000	24.00
7	3.7	37000	750	28125000	2.0	9250000	24.67
8	4.1	41000	750	28125000	2.4	10250000	27.33
9	5	50000	750	28125000	2.7	12500000	33.33
10	5.5	55000	750	28125000	3.0	13750000	36.67
11	6.3	63000	750	28125000	5.0	15750000	42.00
12	6.6	66000	750	28125000	5.2	16500000	44.00
13	6.5	65000	750	28125000	5.4	16250000	43.33
14	6.6	66000	750	28125000	6.7	16500000	44.00
15	6.7	67000	750	28125000	8.6	16750000	44.67

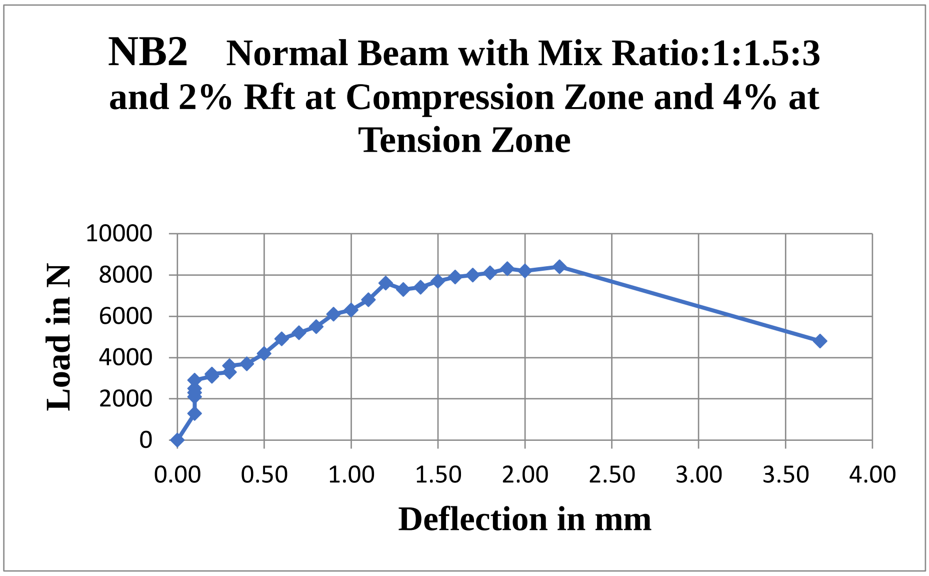
Beam -2 with pure 16mm coarse aggregate

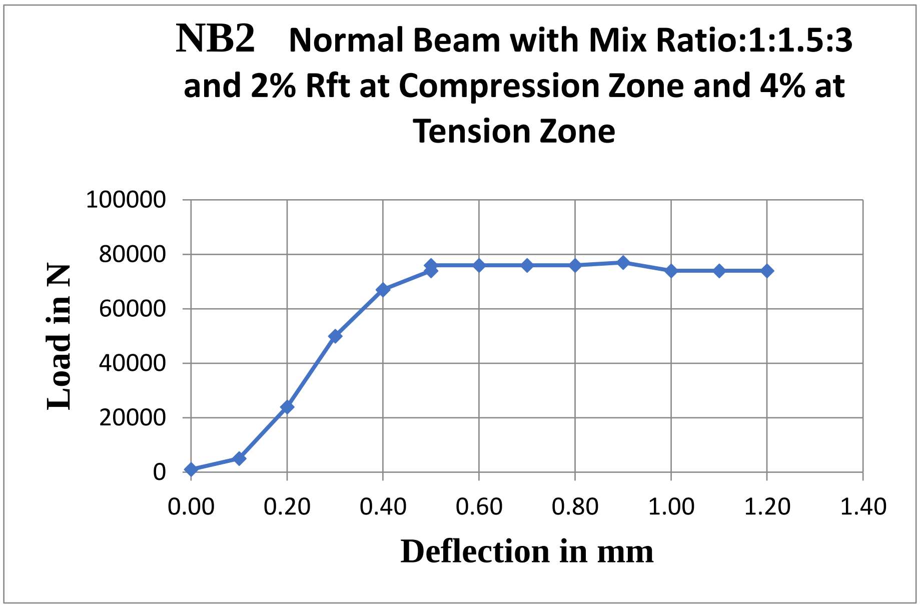
S. No	Load (t)	Load (N)	Length(mm)	Moment of Inertia (mm^4)	Deflection (mm)	Bending moment M=(WL/3)	Bending stress (N/mm^2)
1	0	0	750	28125000	0.0	0	0.00
2	0.1	1000	750	28125000	0.0	250000	0.67
3	0.8	8000	750	28125000	0.5	2000000	5.33
4	1.1	11000	750	28125000	0.6	2750000	7.33
5	1.4	14000	750	28125000	0.7	3500000	9.33
6	1.7	17000	750	28125000	0.8	4250000	11.33
7	2.1	21000	750	28125000	0.9	5250000	14.00
8	2.4	24000	750	28125000	1	6000000	16.00
9	3	30000	750	28125000	1.2	7500000	20.00
10	3.2	32000	750	28125000	1.6	8000000	21.33

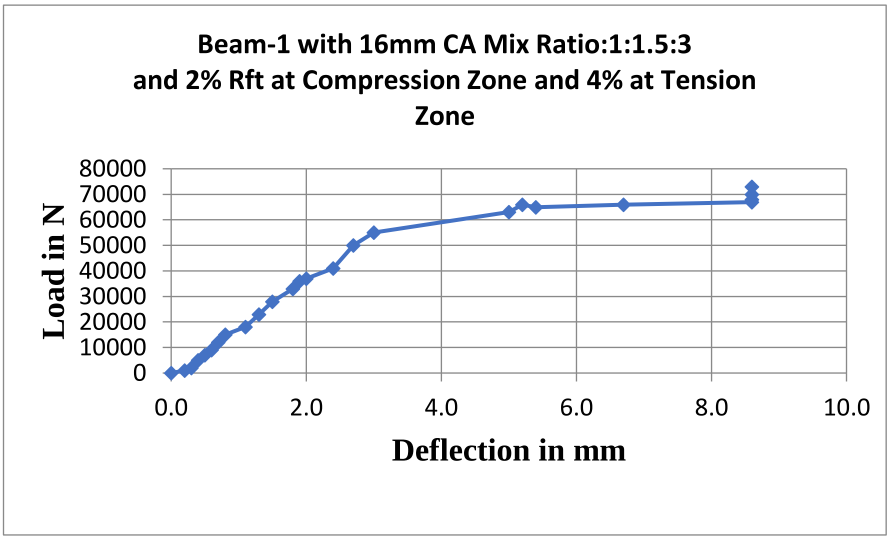
11	3.5	35000	750	28125000	1.8	8750000	23.33
12	3.6	36000	750	28125000	1.9	9000000	24.00
13	6.5	65000	750	28125000	2	16250000	43.33

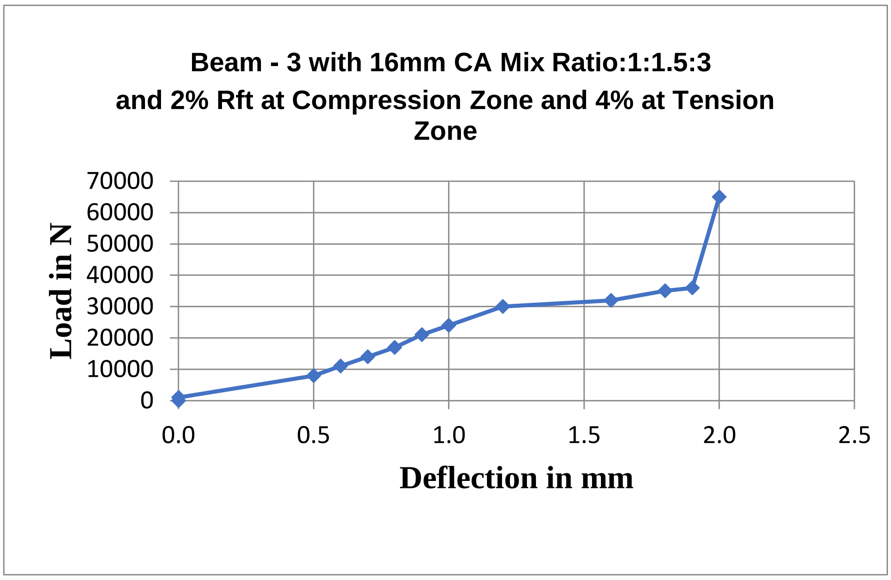
Beam -3 with pure 16mm coarse aggregate							
S. No	Load (t)	Load (N)	Length (mm)	Moment of Inertia (mm^4)	Deflection (mm)	Bending moment M=(WL/3)	Bending stress (N/mm^2)
1	0	0	750	28125000	0.0	0	0.00
2	0.1	1000	750	28125000	0.0	250000	0.67
3	0.8	8000	750	28125000	0.5	2000000	5.33
4	1.1	11000	750	28125000	0.6	2750000	7.33
5	1.4	14000	750	28125000	0.7	3500000	9.33
6	1.7	17000	750	28125000	0.8	4250000	11.33
7	2.1	21000	750	28125000	0.9	5250000	14.00
8	2.4	24000	750	28125000	1	6000000	16.00
9	3	30000	750	28125000	1.2	7500000	20.00
10	3.2	32000	750	28125000	1.6	8000000	21.33
11	3.5	35000	750	28125000	1.8	8750000	23.33
12	3.6	36000	750	28125000	1.9	9000000	24.00
13	6.5	65000	750	28125000	2	16250000	43.33

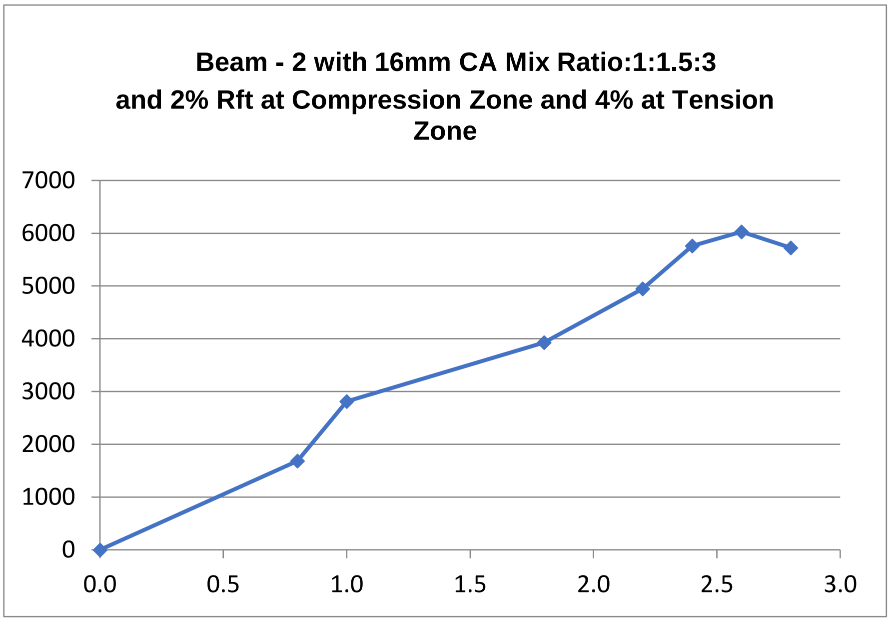



NB2 Normal Beam with Mix Ratio:1:1.5:3 and 2% Rft at Compression Zone and 4% at Tension Zone
Load in N
10000
8000
6000
4000
2000
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Deflection in mm


NB2 Normal Beam with Mix Ratio:1:1.5:3 and 2% Rft at Compression Zone and 4% at Tension Zone
Load in N
100000
80000
60000
40000
20000
0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
Deflection in mm


Beam-1 with 16mm CA Mix Ratio:1:1.5:3 and 2% Rft at Compression Zone and 4% at Tension Zone
Load in N
80000
70000
60000
50000
40000
30000
20000
10000
0
0.0
2.0
4.0
6.0
8.0
10.0
Deflection in mm





MODE OF FLEXURAL FAILURES:

The use of purely 16mm CA does not reduces the strength of beams (ultimate limit state) but the stiffness (serviceability limit state) of the structure. Unfortunately, the increase in strength and

stiffness is sometimes realized at the expense of loss in ductility and brittle failure occurs

and the most common failure modes of RC beams casted with 16mm CA are

1. Compression failure: This type of failure has a brittle nature and occurs rapidly without previous warning when the concrete attains its ultimate compressive strain while the steel strains are relatively low. The section failed in this mode Is brittle.

2. Tension failure: This type of failure has a ductile nature and it provides sample warning against failure. The section failed in this mode is lightly reinforced. When failure occurs, it will be initiated by yielding of the reinforcing steel on the tension side. This type of failure is favorable because it provides the maximum flexural capacity with a minimal reinforcement.

3. Rupture: The rapture follows the yielding of reinforcing steel in tension before the concrete attains the ultimate compressive strain. This type of failure is less ductile failure. It is obvious that the type of failure depends on the grading of aggregate. To determine the failure mode.

CONCLUSIONS:

In the laboratory no different combination of CA are used in concrete beam. After obtaining the result of flexural strength of concrete beam casted with 16mm CA. Following are the conclusion:

- The flexure strength increases affected rapidly by the rupture of concrete before it reaches its ultimate load.
- As size of CA increases the strength also increases but the ductile nature of Beam get reduced by the voids.
- For higher grade of concrete higher flexure strength is obtained.

Future Scope

- Different combination of 16mm CA with smaller fraction can solve the defect.
- Mineral admixtures may be used to reduce the voids.
- Use of fibers may increase the ductility of concrete as well.

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