A
PROJECT REPORT

ON

THE STUDY OF THE BEHAVIOUR OF SIMPLY SUPPORTED PLAIN CONCRETE & STEEL REINFORCED CONCRETE BEAMS WITH CIRCULAR OPENING

SUBMITTED IN THE PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF DEGREE OF

MASTER OF ENGINEERING
(STRUCTURAL ENGINEERING)

SUBMITTED BY:

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2009-2011

CERTIFICATE

It is certified that the work presented in this thesis entitled **"THE STUDY OF THE BEHAVIOUR OF SIMPLY SUPPORTED PLAIN CONCRETE & STEEL REINFORCED CONCRETE BEAMS WITH CIRCULAR OPENING"** by **Anoop Nair, University Roll No. 9074** in partial fulfillment of the requirement for the award of the degree of Master of Engineering in Structural Engineering, Delhi Technological University (Formerly Delhi College of Engineering), Delhi, is an authentic record. The work is being carried out by him under our guidance and supervision in the academic year 2010-2011. This is to our knowledge has reached requisite standards.

The matter embodied in this project has not been submitted for the award of any degree.

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ACKNOWLEDGEMENT

It is a matter of great pleasure for me to present my thesis report on **"THE STUDY OF THE BEHAVIOUR OF SIMPLY SUPPORTED PLAIN CONCRETE & STEEL REINFORCED CONCRETE BEAMS WITH CIRCULAR OPENING"**. First and foremost, I am profoundly grateful to my project guide **Dr. A. K. Gupta (PT)**, Professor of Civil and Environment Engineering Department and for their expert guidance and continuous encouragement during all stages of thesis. Their help in the form of valuable information and research thoughts at proper time has brought life in this thesis. I feel lucky to have got an opportunity to work with him. I am thankful to the kindness and generosity shown by him towards me, as it helped me morally to complete the project.

I am grateful to my parents for their moral support all the time; they have been always around to cheer me up, in the odd times of this work. I am also thankful to my classmates for their unconditional support and motivation during this work.

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ABSTRACT

This study deals with the behavior of simply supported Plain concrete & Steel Reinforced Concrete beams with circular opening. In general construction practice beams with vertical and horizontal openings are necessary at various locations in the structure. These openings may be provided for passage of fresh water & sewage piping or conduits or ducts in residential & industrial structures. These opening provided in the beams decreases the load carrying capability of the R.C.C beam drastically in comparison to the design strength of the beam with no opening. The reduction in strength is a factor of various variables like diameter of opening, shape of opening, location of opening etc.

In this study a number of Plain concrete and R.C.C beams were cast, with and without opening and various other factors were varied like diameter of opening, location of the openings, area of tension & compression reinforcement, spacing of shear reinforcement etc., were varied to establish the effect of variation of all these parameters on the beam strength and to develop the relationships between these variables and strength of the beam.

The beams were tested according to the relevant Indian Standards; the beams underwent the following tests during the course of the preparation of this report;

1. Load deflection test- Two Point Load.
2. Flexure Test- Two Point Load.
3. Uniaxial Compression Test (cubes)
4. Ultrasonic Pulse Velocity (U.P.V).
5. Rebound Hammer Test,

The data from the above tests were analyzed and compared with the F.E.M model of the plain concrete beams to establish different relationships defining the behavior of such structural members.

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CHAPTER 1

INTRODUCTION

1.1 Topic Overview

In the construction industry various unique problems arise in the day to day progress of work, and one such problem has been selected here to be studied. At various construction projects sometimes it is unavoidable to provide openings (horizontal or vertical) in RCC beams, these openings are generally left to for pipes, cables, ducts etc. to pass through. These types of problems are very common in big industrial projects, where the some new construction has to be done alongside existing machines or building, in these cases moving a particular obstruction may result in the loss of efficiency of the existing machines or may not even be possible at all, also it may not be financially viable to shut a plant down for long period of construction.

Generally two cases arise out from the above stated:-

a. When the circular opening has its axis horizontal
b. When the circular opening has its opening vertical.

Numerous studies have been carried out for the first case, in both steel & RCC beams, but for the latter not much research has been done. The vertical opening provided in the beam may affect the beams behavior and strength in the following manner;

a. Reduction in shear capacity, as the cross-sectional area of the beam is reduced
b. Reduction is flexural capacity, as the area of concrete is largely reduces in the compression zone of the beam.
c. Large deflections may occur in the beam, as the reduction in the cross-sectional area also reduces the moment of inertia & stiffness of the beam, at the opening.
d. Reduction in load carrying capacity due to stress concentration in the vicinity of the opening.

This project was conducted in two stages:-

a. Study of plain concrete beams with openings.
b. Study of R.C.C Beams with openings.

To check for the quality/homogeneity of the specimen prepared all of the above samples were subjected to test such as UPV & Rebound hammer. The concrete cubes cast along with each set of beams were subjected to uniaxial compression test to assess the compressive strength of each batch of the concrete sample.

The plain concrete & R.C.C beams were mainly subjected to the load deflection test; the load was applied as a two point load on the simply supported beam. The load was gradually increased and the deflection at the corresponding loads was taken.

Fig.1.1.Steel beam with transverse opening. [1]

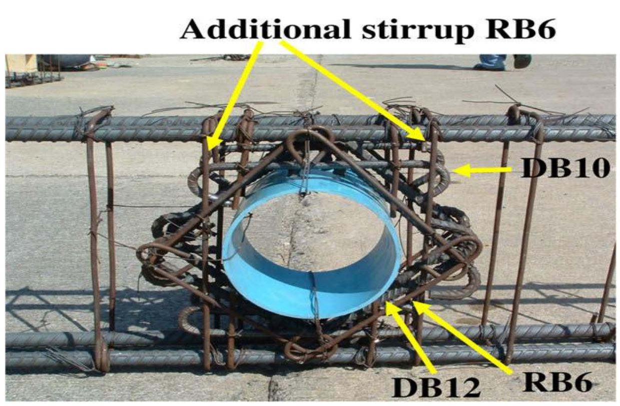


Fig.1.2.RCC beam steel detailing for transverse opening [2] -

10The load-deflection behavior of a beam is of prime importance, as due to the reduction of the Moment of Inertia of the beam section, the stiffness of the beam reduces considerably, leading to larger deflection in these types of beams compared to the normal beams.

1.2 Problems posed by provision of opening in a beam:

1. The beam opening causes considerable reduction of concrete area in the compression zone, and may cause sudden/brittle failure of the beam

2. The openings in a RCC beam poses a serious problem when the reinforcement are to be laid, as the reinforcement may have to be bundled together in the vicinity of the opening, causing stress concentration, which may lead to early failure of the beam.

3. These beams may have larger amount deflection than the normal beams, which may pose a serious problem where deflection tolerances are very stringent.

4. If the opening is located near the supports the, the considerable reduction in the cross-sectional area may cause shear failures without notice at much lower loads than anticipated.

1.3 Objectives of the study

1. To study the Load-Deflection behavior of Plain & R.C.C beams with opening.
2. To study the failure characteristics of the Plain & R.C.C beams with opening.

CHAPTER 2

LITERATURE REVIEW

2.1 General

Literature available for this particular project was quite negligible; most of the literature referred was for the F.E.M modeling. The modeling required the accurate assessment of the properties of the concrete through various test and relationships put forward by many researchers.

2.2 Estimation of Elasticity constants of concrete using UPV

The relation between the dynamic modulus of elasticity and the UPV values is as follows:-

$$\mathbf{UPV = ((E_d\ .\ (1-\nu))/(\rho.(1+\nu).(1-2.\ \nu)))^{1/2}}$$

Where, UPV= ultrasonic pulse velocity (m/sec)

E_d = dynamic modulus of elasticity

ρ = Density of concrete (kg/cum)

ν = Poisson's ratio

Mesbah et al [3] reported that the dynamic poisons ratio for high performance concrete which contained silica fume as cement replacement increased from 0.16 to 0.24 and 0.19 to 0.23, from day 1 to day 7, for concrete with water cement ratio of 0.35 and 0.45, respectively. The marked early age increase in dynamic Poisson's ratio is likely to be attributed to the presence of silica fume. Other researchers, have revealed that for mixture without silica fume, the poisons ratio is not very sensitive to age or richness of the concrete mixture, and suggested a ratio of 0.19 [4]. Also stated in this report was the fact that the ratio of Dynamic to Static modulus of elasticity (E_d/E_s) approaches equilibrium value of around 1.2 to 1.3.[5]

2.3 Estimation of Elastic Modulus of elasticity using formulas in various codes

Review of the various internationals codes brought forward the following equations for the estimation of the Static elastic modulus:-[5]

1. ACI 363

   $E_S = 6900+3300.(f'_C)^{1/2}$ for $21MPa < f'_C < 83MPa$

   $f'_C = 30$ N/sqmm $E_S = 24974.844$ N/sqmm

2. ACI318/AASHTO

   $E_S = 0.043\, w_C^{1.5} (f'_C)^{1/2}$ for $1500kg/m^3 < f'_C < 2400kg/m^3$

   $f'_C = 30$ N/sqmm $w_C = 2318.73$kg/cum $E_S = 26296.888$N/sqmm

3. EuroCode2

   $E_S = 21500.(f'_C / 10)^{2/3}$

   $f'_C = 30$ N/sqmm $E_s = 44721.8022$N/sqmm

4. Gardner & Lockman

   $E_S = 3500+4300.(f'_C)^{1/2}$

   $f'_C = 30$ N/sqmm $E_s = 27052.07$N/sqmm

5. IS 456 (2000)

   $E_S = 5000(f'_C)^{1/2}$

   $f'_C = 30$ N/sqmm $E_s = 27386.128$N/sqmm

The study of the above codes showed that the value of static modulus of elasticity of concrete is almost the same for Indian Code[IS 456:2000] & Gardner & Lockman [5]. The EuroCode2 over estimates the value by 38-43%[5], according to D.K Panesar& B.Shinman[5], eqs.2 & 4 predicts the static modulus the closest. No single prediction equation best estimates the elastic properties at early(1-3days) and later(28-56days)ages Eqs.4 predicts closer to the tested value for concrete at day 1, 3 and 7, whereas eqs.2. predicts closer to the test value at 28 and 56 days.

So for the Purpose of finite element modeling the value from eqs.2. can be used for greater accuracy in the results

CHAPTER 3

MATERIAL

3.1 CONCRETE (For Plain concrete Beams)

The grade of concrete used for the P.C.C beam specimens was **M30** with the following mix proportion:-

1. Cement = 418kg/m^3 (Rock Strong-PPC)
2. Fine Aggregate = 627kg/m^3 (Zone-III)
3. Coarse Aggregate = 1254kg/m^3 -20mm : 10mm (65:35)
4. Super plasticizer = 1.5% weight of cement (Sika)
5. W/C ratio = 0.40

Design parameters:-

1. Slump:- 150mm
2. Exposure condition:- Moderate

Codes followed for mix design:-

1. IS 456: 2000 Plain & Reinforced Concrete- Code of Practice(4th Revision)
2. IS 10262:2009 Concrete Mix proportions Guidelines(1st Revision)

3.2 STEEL REINFORCEMENT

Properties:-

1. Grade & Name - Fe-500 (Ribbed bars) – Tiscon T.M.T
2. Manufacturer:- Tata
3. Diameters Used:- 12mm,10mm & 8mm

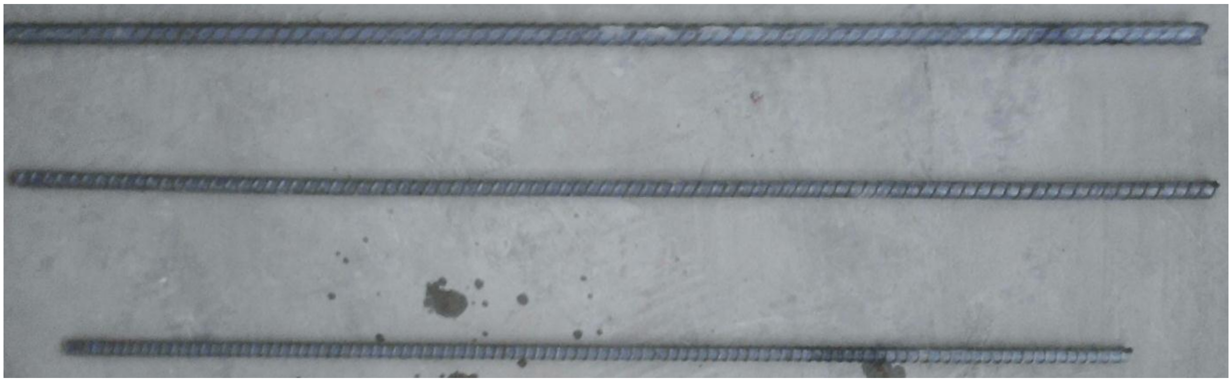


Fig-3.1.Steel reinforcement bars Used (12mm,10mm &8mm)

CHAPTER 4

Test Specimen Preparation

4.1 Plain concrete beam preparation:-

Fig-4.1.Weighing of batch of material for concrete mix

fig-4.2.Mixing of a Batch.

Fig-4.3.Concrete mix after mixing.

Fig-4.4.Clean & oiled standard beam & cube moulds for casting

Fig-4.5. Standard cube after casting(15cm)

fig-4.6.Standard beam Specimen after casting (150mmx150mmx700mm)

Fig-4.7.Casting of beams with Openings using PVC inserts

Fig-4.8.Demoulding of the Specimen.

fig-4.9.All the specimens were cured for a period of 28 days in curing tanks

fig-4.10.Beams after 28 days of curing

Table-4.1. List of Various types of Plain Concrete beam specimens made:

Slno	L (mm)	B (mm)	D (mm)	Opening Dia (mm)	Dist From Edge (mm)	Opening Zone
1	700	150	150	-	-	-
2	700	150	150	-	-	-
3	700	150	150	-	-	-
4	700	150	150	-	-	-
5	700	150	150	-	-	-
6	700	150	150	-	-	-
7	700	150	150	-	-	-
8	700	150	150	-	-	-
9	700	150	150	50.00	350.00	-
10	700	150	150	50.00	90.00	shear
11	700	150	150	50.00	230.00	shear
12	700	150	150	50.00	185.00	shear
13	700	150	150	40.00	350.00	Flexure
14	700	150	150	40.00	90.00	shear
15	700	150	150	40.00	215.00	shear
16	700	150	150	40.00	230.00	shear
17	700	150	150	63.00	350.00	Flexure
18	700	150	150	63.00	95.00	shear
19	700	150	150	63.00	120.00	shear
20	700	150	150	63.00	200.00	shear
21	700	150	150	75.00	350.00	Flexure
22	700	150	150	75.00	90.00	shear
23	700	150	150	75.00	200.00	shear

4.2 R.C.C beam preparation:-

Fig-4.11. Fabrication of reinforcement bars

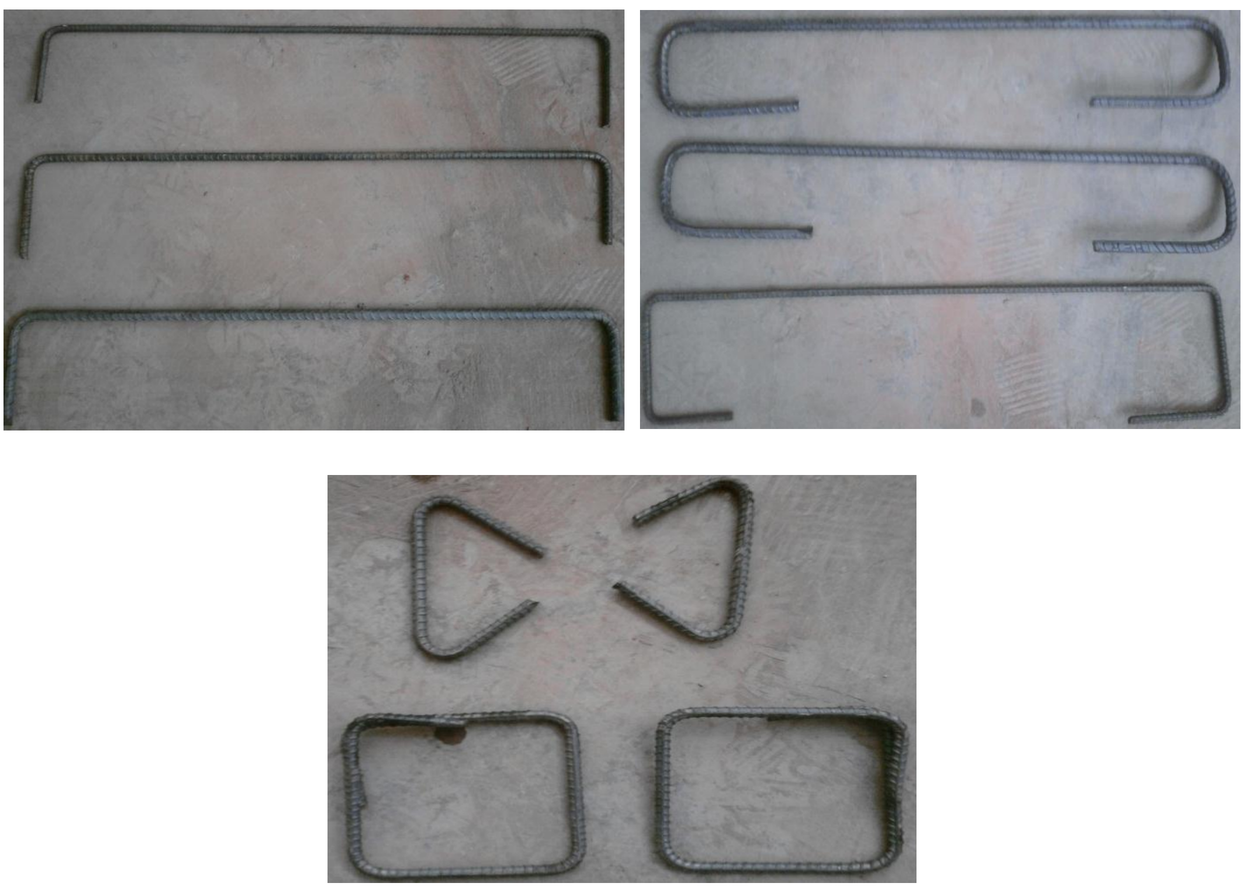


Fig-4.12.Fabricated Steel reinforcements

Fig-4.13. Steel reinforcement ready to be placed in beam moulds

Fig-4.14. Beams ready to be cast (with & without shear reinforcements)

Fig.4.15.Casting of R.C.C beams

Fig.4.16. R.C.C Beam de-moulded, ready for curing

Fig.4.17.R.C.C beams under moist curing for 28 days

Table 4.2. List of Various types of R.C.C beam specimen made

Beam .No	Length (mm)	Breadth (mm)	Depth (mm)	Cover (mm)	Effective Depth (mm)	d' (mm)	fck (N/sqmm)	Fy (N/sqmm)	TENSION REINF		TOP-REINF		SHEAR REINF		
									DIA (mm)	NO	DIA (mm)	NO	DIA (mm)	LEGS	SPACING (mm)
1	700	150	150	10	140	-	28.78	500	8	2	-	-	-	-	-
2	700	150	150	10	140	-	28.78	500	10	2	-	-	-	-	-
3	700	150	150	10	140	-	28.78	500	12	2	-	-	-	-	-
4	700	150	150	10	140	-	27.73	500	8	2	-	-	-	-	-
5	700	150	150	10	140	-	27.73	500	10	2	-	-	-	-	-
6	700	150	150	10	140	-	27.73	500	12	2	-	-	-	-	-
7	700	150	150	10	140	20	29.20	500	10	2	8	2	-	-	-
8	700	150	150	10	140	20	29.20	500	10	2	10	2	-	-	-
9	700	150	1500	10	140	20	29.20	500	10	2	12	2	-	-	-
10	700	150	150	10	140	20	33.92	500	8	2	8	2	8	2	100
11	700	150	150	10	140	20	33.92	500	8	2	8	2	8	2	75
12	700	150	150	10	140	20	33.92	500	8	2	8	2	8	2	50

CHAPTER 5

TESTS FOR ASSESMENT OF STRENGTH AND QUALITY OF CONCRETE SPECIMEN

5.1 Tests conducted on samples:-

a. Uniaxial Compression test.
b. Ultra Sound Pulse Velocity.
c. Rebound Hammer test.

These tests were conducted on the samples to estimate the quality of the samples, and to judge their engineering properties for the purpose of modeling.

5.2 Uniaxial compression test of concrete and its result:-

This test was conducted is accordance to the Indian standard code,
IS-516:1959(reaffirmed-1999). The results for the specimens tested are as follows.

Table.5.1.Cube Test Results:- (P.C.C Beams)

DATE	SAMPLE					AVG LOAD (KN)	AVG STRESS (N/mm2)
	1	2	3	4	5		
1/18/2011	700	710	740			716.67	31.85
	700	740	780			740.00	32.89
1/20/2011	730	730	740			733.33	32.59
1/21/2011	660	690	700			683.33	30.37
1/27/2011	870	700	730			766.67	34.07
2/1/2011	820	920	930	840		877.50	39.00
2/4/2011	810	720	810	860	820	804.00	35.73
2/9/2011	650	760	750			720.00	32.00

Table.5.2.Cube Test Results:- (R.C.C Beams)

DATE	SAMPLE					AVG LOAD (KN)	AVG STRESS (N/mm2)
	1	2	3	4	5		
23/5/2011	600	570	670	750		647.5	28.78
30/5/2011	645	660	666			657	29.20
2/6/2011	770	730	790			763.33	33.92
6/6/2011	630	620	620			623.33	27.73

Fig.5.1. Compression Testing of Standard 15cm concrete cubes

5.3 UPV Test Procedure & Results:-

Objective of the test:-

The main objectives of the test are:-

a. To assess the quality of concrete.
b. To predict the elastic constants of the concrete mix.

5.3.1 Procedure:-

1. Preparation of surfaces:-
   All the surfaces required to be probed, were cleaned using sand paper and then wiped clean using damp cloth to remove all laitance and dirt.

Fig5.2. Preparation of surfaces (Sanding & cleaning with damp cloth)

2. Marking of the beam:-
   The beams to be tested are marked with grid lines to locate the points, where the receiver and the transmitters are to be held, this gives us known length of propagation of ultrasonic pulses.

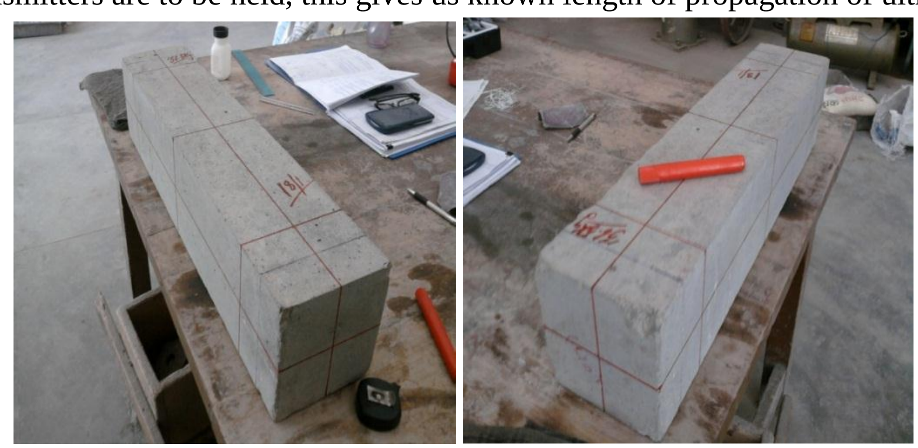


Fig.5.3. Marking of the beam

3. Different arrangement of transducers and path length:-

a. Direct transmission (150mm,700mm)

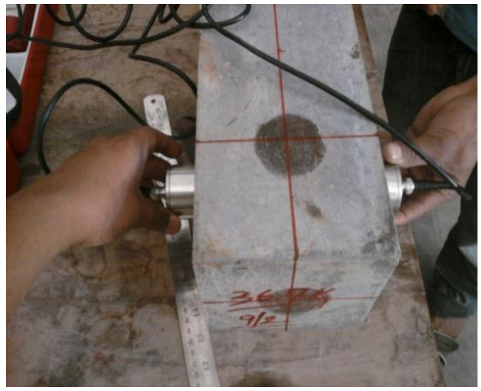


Fig.5.4. Direct transmission

b. Semi direct Transmission (125mm, 357.95mm, 604.669mm,106.066mm)

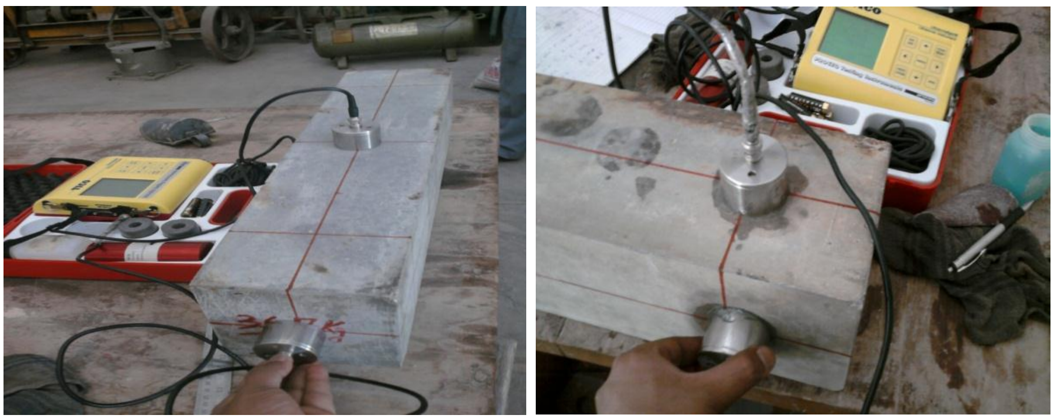


Fig.5.5. Semi direct Transmission

c. Indirect Transmission (250mm,500mm)

Fig.5.6. Indirect Transmission

4. Calibration of the UPV apparatus:-

Fig.5.7. calibration using standard prism

5. Application of Coupling Gel on the Transmitter & Receiver

Fig.5.8. Application of Coupling Gel on the Transmitter & Receiver

Fig.5.9. Complete U.P.V apparatus/kit

5.3.2 UPV Results & Analysis:-

Table.5.3.SAMPLE-1

DATE OF CASTING	9/2/2011
OPENING DIA(mm)	0
WEIGHT (kg)	36.7
DENSITY (kg/cum)	2330.15873
Grade	M30

S.No	**Time (µsec)**	**Path Length (mm)**	**Velocity(km/hr)**
1	25.4	125	4.92
2	24.7	125	5.06
3	75.8	357.946	4.72
4	74.9	357.946	4.78
5	131.7	604.669	4.59
6	131.6	604.669	4.59
7	31.9	150	4.70
8	31.3	150	4.79
9	31.8	150	4.72
10	20.3	106.066	5.22
11	20.5	106.066	5.17
12	20	106.066	5.30
13	19.4	106.066	5.47
14	19.7	106.066	5.38
15	19.7	106.066	5.38
16	72.8	250	3.43
17	140.4	500	3.56

Average velocity(km/sec)	4.987890188	Very good quality concrete

Table.5.4.SAMPLE -2

DATE OF CASTING	9/2/2011
OPENING DIA(mm)	0
WEIGHT (kg)	36.4
DENSITY (kg/cum)	2311.111111
Grade	M30

S.No	**Time (µsec)**	**Path Length (mm)**	**Velocity(km/sec)**
1	25.3	125	4.94
2	27.8	125	4.50
3	76.4	357.946	4.69
4	77.3	357.946	4.63
5	130.6	604.669	4.63
6	138.8	604.669	4.36
7	32.9	150	4.56
8	32.2	150	4.66
9	32.2	150	4.66
10	23.9	106.066	4.44
11	23.5	106.066	4.51
12	21.5	106.066	4.93
13	152.3	700	4.60
14	146.1	500	3.42
15	72	250	3.47

Average velocity(km/sec)	4.622777302	Very good quality concrete

Table.5.5.SAMPLE-3

DATE OF CASTING	9/2/2011
OPENING DIA(mm)	0
WEIGHT (kg)	36.4
DENSITY (kg/cum)	2311.111111
Grade	M30

S.No	**Time (µsec)**	**Path Length (mm)**	**Velocity(km/hr)**
1	26	125	4.81
2	29.6	125	4.22
3	77.2	357.946	4.64
4	77.7	357.946	4.61
5	133.8	604.669	4.52
6	131.8	604.669	4.59
7	32.9	150	4.56
8	33.4	150	4.49
9	32.6	150	4.60
10	22.9	106.066	4.63
11	21.7	106.066	4.89
12	30.7	106.066	3.45
13	157.3	700	4.45
14	73.4	250	3.41
15	138.8	500	3.60

Average velocity(km/sec)	4.49669884	Very good quality concrete

Table.5.6.SAMPLE-4

DATE OF CASTING	9/2/2011
OPENING DIA(mm)	0
WEIGHT (kg)	36.6
DENSITY (kg/cum)	2323.809524
Grade	M30

S.No	**Time (µsec)**	**Path Length (mm)**	**Velocity(km/hr)**
1	26.5	125	4.72
2	23.9	125	5.23
3	78.3	357.946	4.57
4	74	357.946	4.84
5	133.1	604.669	4.54
6	132.7	604.669	4.56
7	34.4	150	4.36
8	32.6	150	4.60
9	32.8	150	4.57
10	21.1	106.066	5.03
11	23.2	106.066	4.57
12	21.2	106.066	5.00
13	150.4	700	4.65
14	77.7	250	3.22
15	143.3	500	3.49

Average velocity(km/sec)	4.711244551	Very good quality concrete

Table.5.7.SAMPLE-5

DATE OF CASTING	18/1/2011
OPENING DIA(mm)	0
WEIGHT (kg)	36.5
DENSITY (kg/cum)	2317.460317
Grade	M30

S.No	**Time (µsec)**	**Path Length (mm)**	**Velocity(km/hr)**
1	28.3	125	4.42
2	28.2	125	4.43
3	83.8	357.946	4.27
4	83.5	357.946	4.29
5	133.8	604.669	4.52
6	133.6	604.669	4.53
7	34.5	150	4.35
8	33.9	150	4.42
9	33.7	150	4.45
10	22.8	106.066	4.65
11	21.2	106.066	5.00
12	21.4	106.066	4.96
13	160.2	700	4.37
14	77.8	250	3.21
15	141.3	500	3.54

Average velocity(km/sec)	4.512125302	Very good quality concrete

5.4 Rebound Hammer Test Procedure & Results:-

5.4.1 Objective of the test:-

To assess the strength of the concrete beams, and to verify their gain of strength is same as that of the cube strength.

5.4.2 Procedure:-

1. The surface has to be cleaned off using sandpaper or rubbing stone & cleaned of ay loose debris.

2. The rebound hammer is calibrated on a standard anvil:-

Fig.5.10.Rebound Hammer being calibrated on a 77+-2 Anvil

3. The rebound hammer is now used on the prepared surfaces of the beam, and the readings are taken from the display, the orientation of the beam is to be programed correctly into the control panel.

Fig.5.11.Horizontal R-H application & Vertically Downward-R-H application

fig.5.12.Vertically upward R-H application

5.4.3 Rebound Hammer Test Result:

Table.5.8.Sample -1 9/2/2011

S.no	Oreintation	Rebound values								Average R-Value	Strength (N/sqmm)
		1	2	3	4	5	6	7	8		
1	V-D	38	36	32	33	38	36	32	29	34.25	32.2
2	V-D	30	33	33	33	33	34	33	29	32.25	38.8
3	V-D	38	34	39	34	35	37	40	34	36.375	35.9
4	V-D	34	37	33	35	34	29	32	29	32.875	32.9
5	V-D	32	39	34	37	43	33	36	35	36.125	35.5
6	V-D	35	36	35	32	33	34	38	33	34.5	32.6
										AVG strength (N/sqmm)=	34.65

Table.5.9.Sample-2 9/2/2011

S.no	Oreintation	Rebound values								Average R-Value	Strength (N/sqmm)
		1	2	3	4	5	6	7	8		
1	V-D	37	33	35	35	34	37	34	33	34.75	33.1
2	V-D	35	39	35	38	43	35	33	35	36.625	36.3
3	V-D	35	41	37	41	37	34	38	33	37	37
4	HORI	41	34	34	34	35	32	30	36	34.5	32.6
5	HORI	32	33	31	33	30	34	31		32	38.6
										Average Strength(N/sqmm)=	35.52

Table.5.10.Sample-3 9/2/2011

S.no	Oreintation	Rebound values								Average R-Value	Strength (N/sqmm)
		1	2	3	4	5	6	7	8		
1	V-D	38	34	37	40	36	36	38	40	37.375	37.7
2	V-D	30	34	31	37	36	32	29	34	32.875	29.8
3	V-D	28	33	38	33	34	33	32	29	32.5	29.2
4	V-D	37	32	32	37	37	32	42	35	35.5	34.4
5	HORI	37	39	35	34	35	37	34	35	35.75	34.8
6	HORI	35	37	34	37	34	34	35	36	35.25	33.9
								Average Strength(N/sqmm)=			33.3

Table5.11.Sample-4 9/2/2011

S.no	Oreintation	Rebound values								Average R-Value	Strength (N/sqmm)
		1	2	3	4	5	6	7	8		
1	V-D	31	36	36	35	35	39	35	42	36.125	35
2	V-D	30	35	34	33	36	31	30	31	32.5	29.2
3	V-D	34	32	33	32	30	34	35	33	32.875	29.8
4	V-D	28	33	35	32	33	31	33	31	32	28.4
5	HORI	38	36	37	37	43	37	35	37	37.5	37.9
6	HORI	40	35	36	36	36	37	41	38	37.375	37.7
									Average Strength(N/sqmm)=		33

Table.5.12.Sample-5 (18/1/2011)

S.no	Oreintation	Rebound values								Average R-Value	Strength (N/sqmm)
		1	2	3	4	5	6	7	8		
1	V-D	32	43	44	35	44	38	37	34	38.375	39.5
2	V-D	34	35	35	39	35	37	36	36	35.875	35
3	V-D	33	34	35	43	34	38	36	35	36	35.2
4	HORI	38	41	39	38	40	38	39	39	39	40.6
5	HORI	40	42	38	40	37	38	41	38	39.25	41.1
										Average Strength(N/sqmm)=	38.28

5.6 Analysis of test results of tests conducted

Table.5.13Comparison between Cube Test & R-H Test results:-

DOC	Sample No 1	2	3	4	Avg - Strength (N/sqmm)	Cube Strength (N/sqmm)
18-Jan	32.00	30.00	35.00	38.28	33.82	31.85
20-Jan	32.40	32.60	-	-	32.52	32.67
21-Jan	34.00	32.60			33.30	30.52
27-Jan	32.20	35.90	33.90	-	34.67	34.07
1-Feb	40.20	39.00	33.90	33.90	36.75	39.00
4-Feb	32.20	37.00	32.60	32.80	33.65	35.73
9-Feb	34.65	35.52	33.30	33.00	34.12	32.00

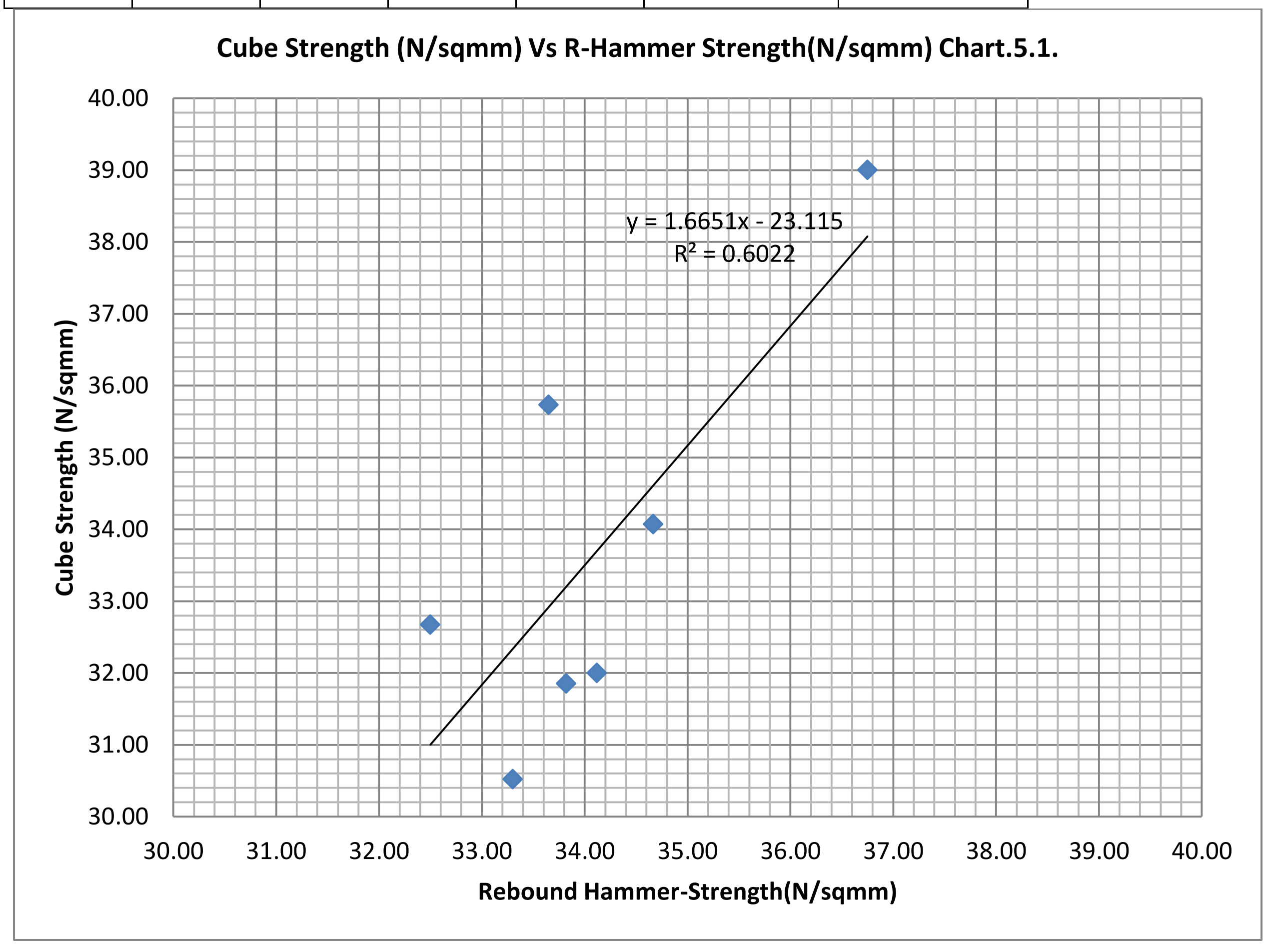


Table.5.14.Comparison between UPV and R-H Test:-

		UPV	Rebound-Hammer		
DOC	**Density(kg/cum)**	**Velocity (km/sec)**	**Strength (Mpa)**	**VER-DWN**	**HORI**
9/2/2011	2330.1587	4.9879	34.4	34.395	-
9/2/2011	2311.1111	4.62278	35.52	36.125	33.25
9/2/2011	2311.1111	4.4967	33.3	34.56	35.5
9/2/2011	2323.8095	4.7112	33.00	33.375	37.438
18/1/2011	2317.4603	4.5121	38.28	37.313	39.125

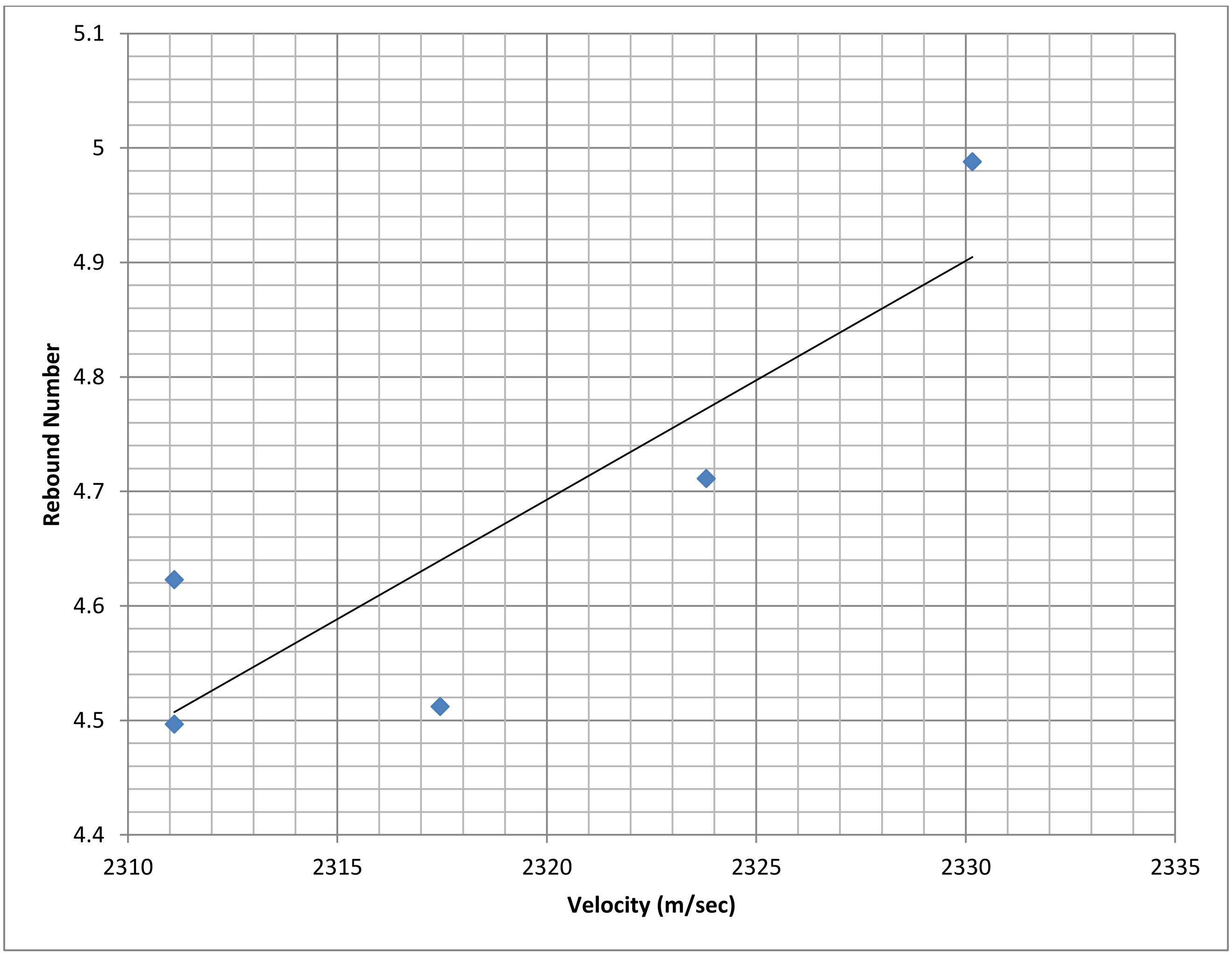
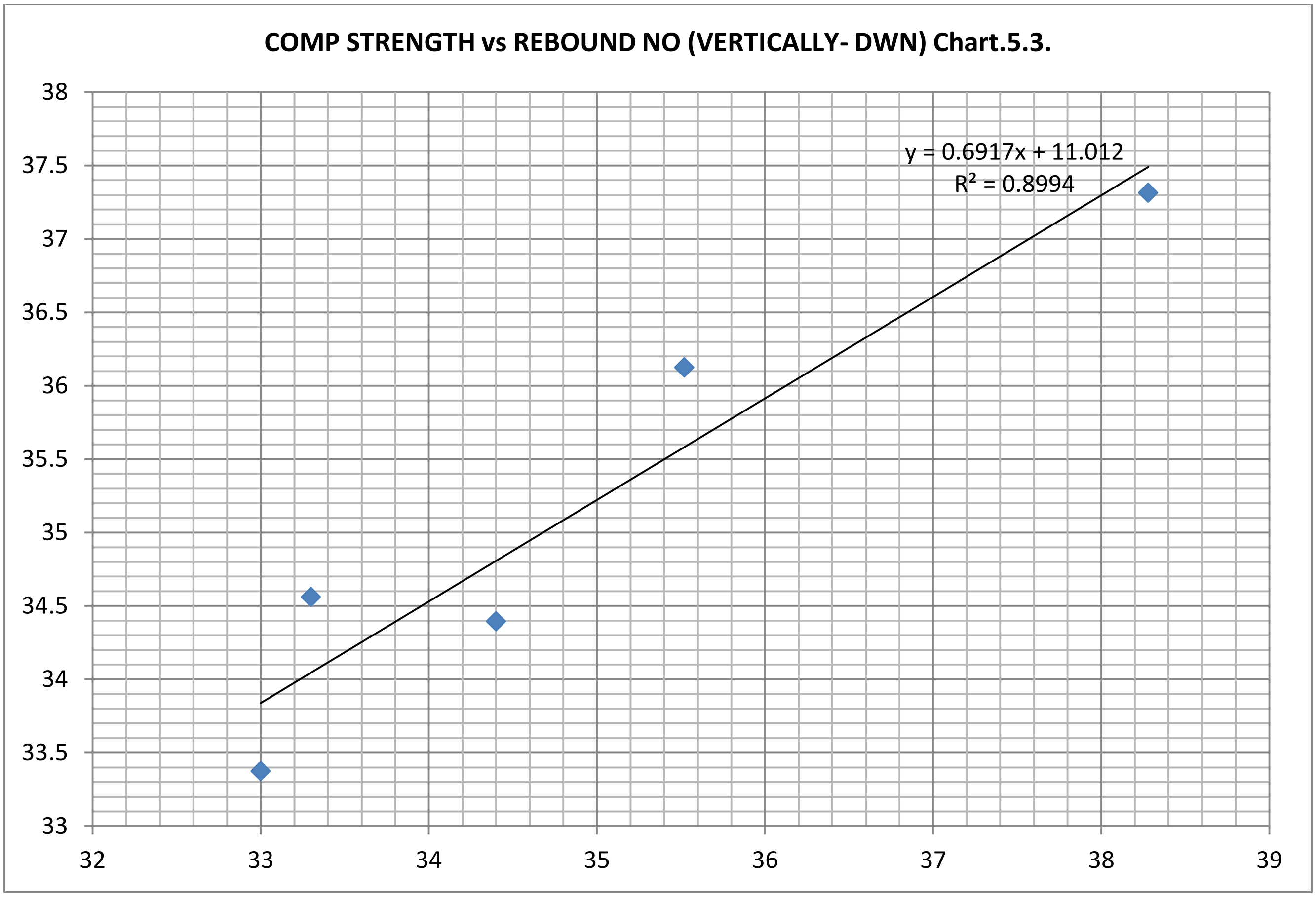


Chart.5.3. Rebound number Vs Veocity(m/sec)


COMP STRENGTH vs REBOUND NO (VERTICALLY- DWN) Chart.5.3.
y = 0.6917x + 11.012
R² = 0.8994
38
37.5
37
36.5
36
35.5
35
34.5
34
33.5
33
32
33
34
35
36
37
38
39

CHAPTER 6

Load Deflection Test

6.1 Objective of the test:-

The load deflection tests were carried out on the beam sample to study the behavior of the beam under a gradually increasing, two point load system. The apparatus was developed

6.1.1. Apparatus:-

1. Support columns
2. Loading Frame
3. Roller Support
4. Slotted weights (20kg,10kg)
5. Dial Gauge (Least Count = 0.01mm)

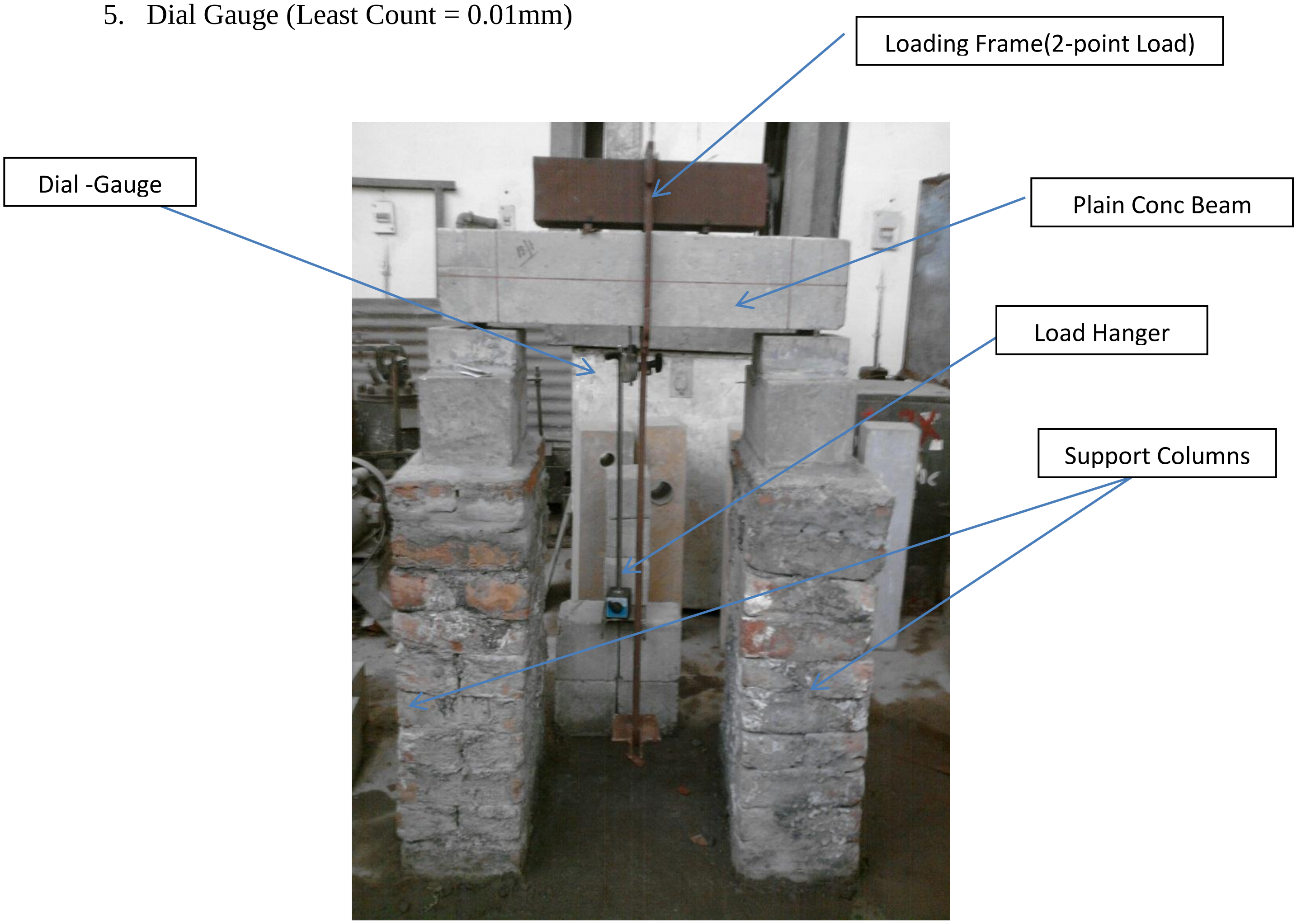


Fig.6.1.Apparatus to determine Load – Deflection Characteristics of Beams (Unloaded)

Fig.6.2.Apparatus to determine Load – Deflection Characteristics of Beams (Fully-Loaded)

6.1.2. Procedure:-

1. The points of supports and loading are marked on to the beam to be tested using a permanent marker.

2. The beam is carefully kept onto the support pillars, and the rollers are inserted below the beam aligning them with the points marked both on the columns and the beam.

3. Next the loading frame in put onto the beam and carefully aligned, with the respective markings.

4. The dial gauge is carefully kept below the beam on a stable platform, and the needle is made to touch the center span. The reading on the dial gauge should beset at zero at zero load.

5. Gradually the slotted weights are kept onto the hanger, and the respective mid span deflection readings are taken from the dial gauge.

6. Now plot the Load vs. Deflection Curve for the Beam.

6.2. **Load vs. Deflection curves for some beams tested**:-

Sample-A

Date of Casting:- 21/1/2011

Opening size:- 0 mm(no opening/Control Beam)

Chart-6.1

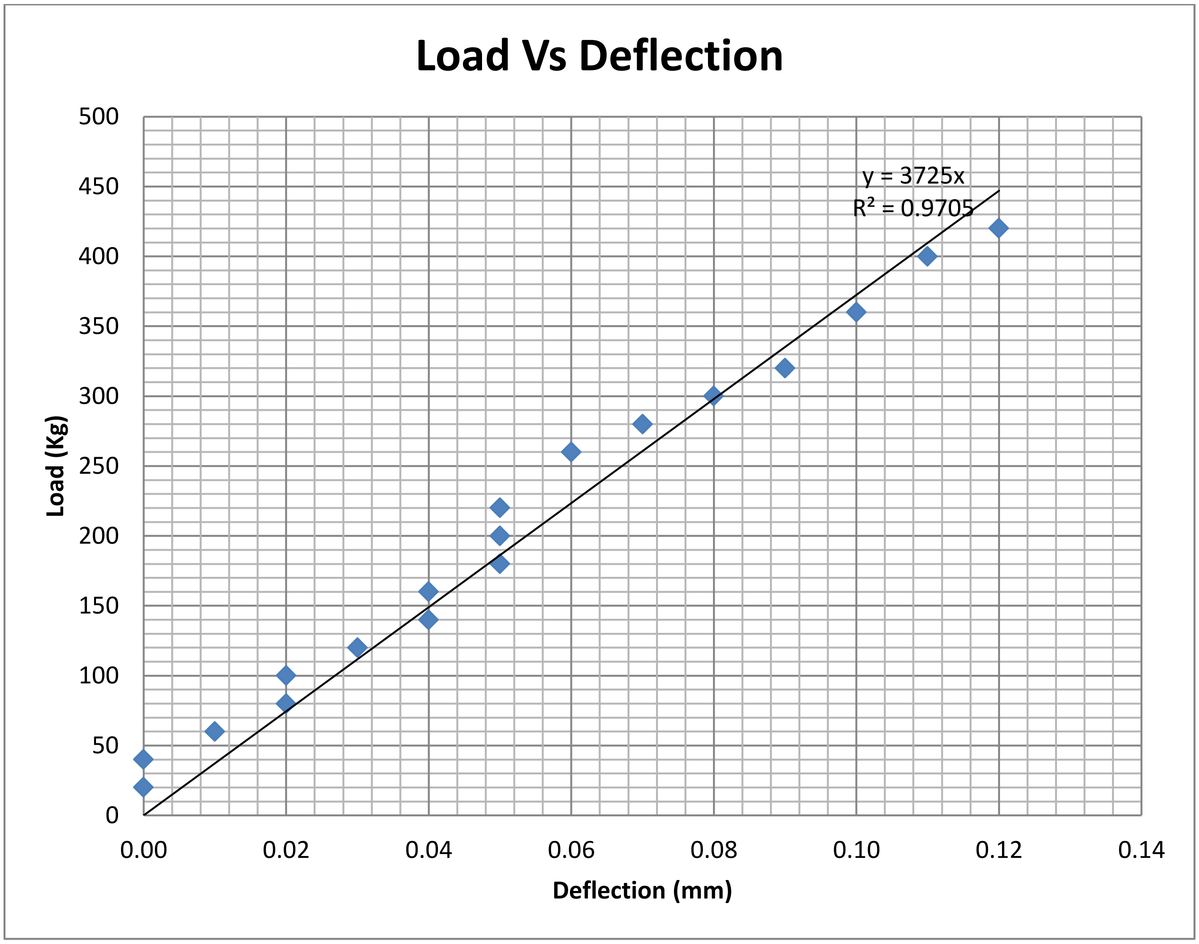


Chart Data:- Table.6.1.

Load(kg)	**Deflection(mm)**
20	0.00
40	0.00
60	0.01
80	0.02
100	0.02
120	0.03
140	0.04
160	0.04
180	0.05
200	0.05
220	0.05
260	0.06
280	0.07
300	0.08
320	0.09
360	0.10
400	0.11
420	0.12

Sample-B

Date of Casting:- 20/1/2011

opening size:- 50mm dia

chart-6.2

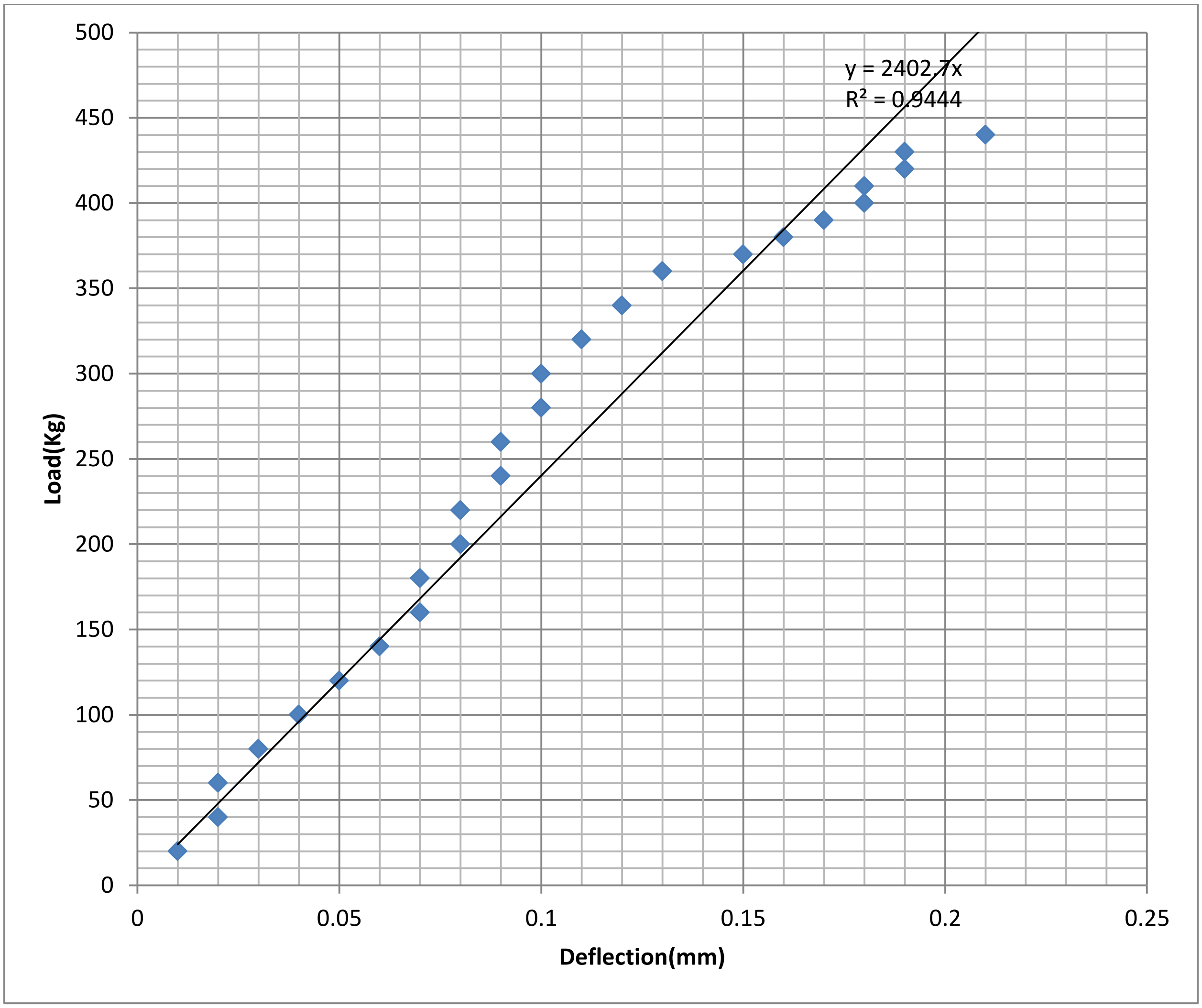


Chart Data:- Table.6.2.

20/1	50
Load(kg)	**Deflection(mm)**
20	0.01
40	0.02
60	0.02
80	0.03
100	0.04
120	0.05
140	0.06
160	0.07
180	0.07
200	0.08
220	0.08
240	0.09
260	0.09
280	0.1
300	0.1
320	0.11
340	0.12
360	0.13
370	0.15
380	0.16
390	0.17
400	0.18
410	0.18
420	0.19
430	0.19
440	0.21

Sample-C

Date of Casting:- 18/1/2011

opening size:- 40mm dia

chart-6.3

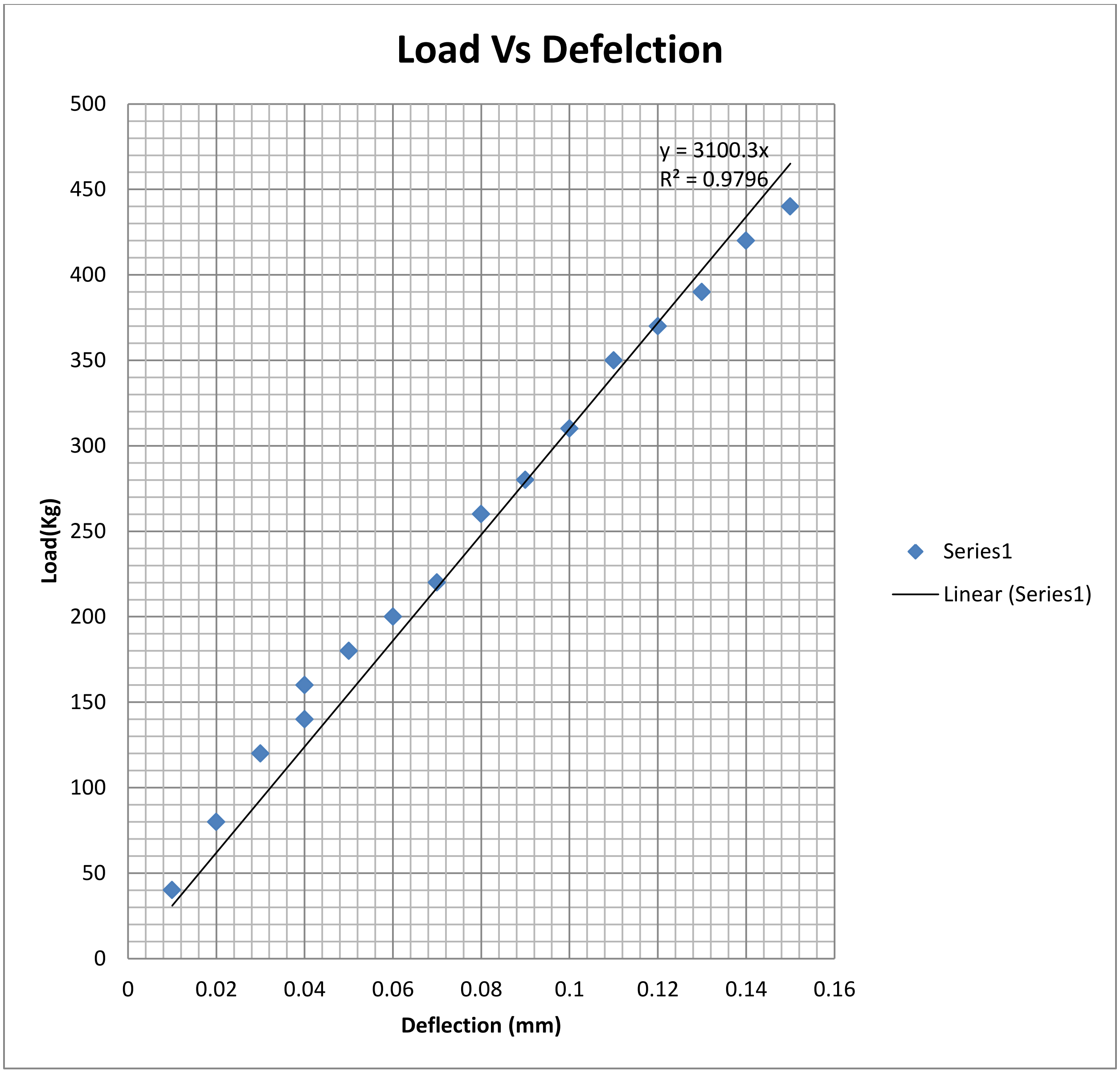


Chart Data:-Table.6.3.

Load(kg)	Deflection(mm)
40	0.01
80	0.02
120	0.03
140	0.04
160	0.04
180	0.05
200	0.06
220	0.07
260	0.08
280	0.09
310	0.1
350	0.11
370	0.12
390	0.13
420	0.14
440	0.15

Sample-D

Date of Casting:- 18/1/2011

opening size:- 63mm dia

Chart-6.4

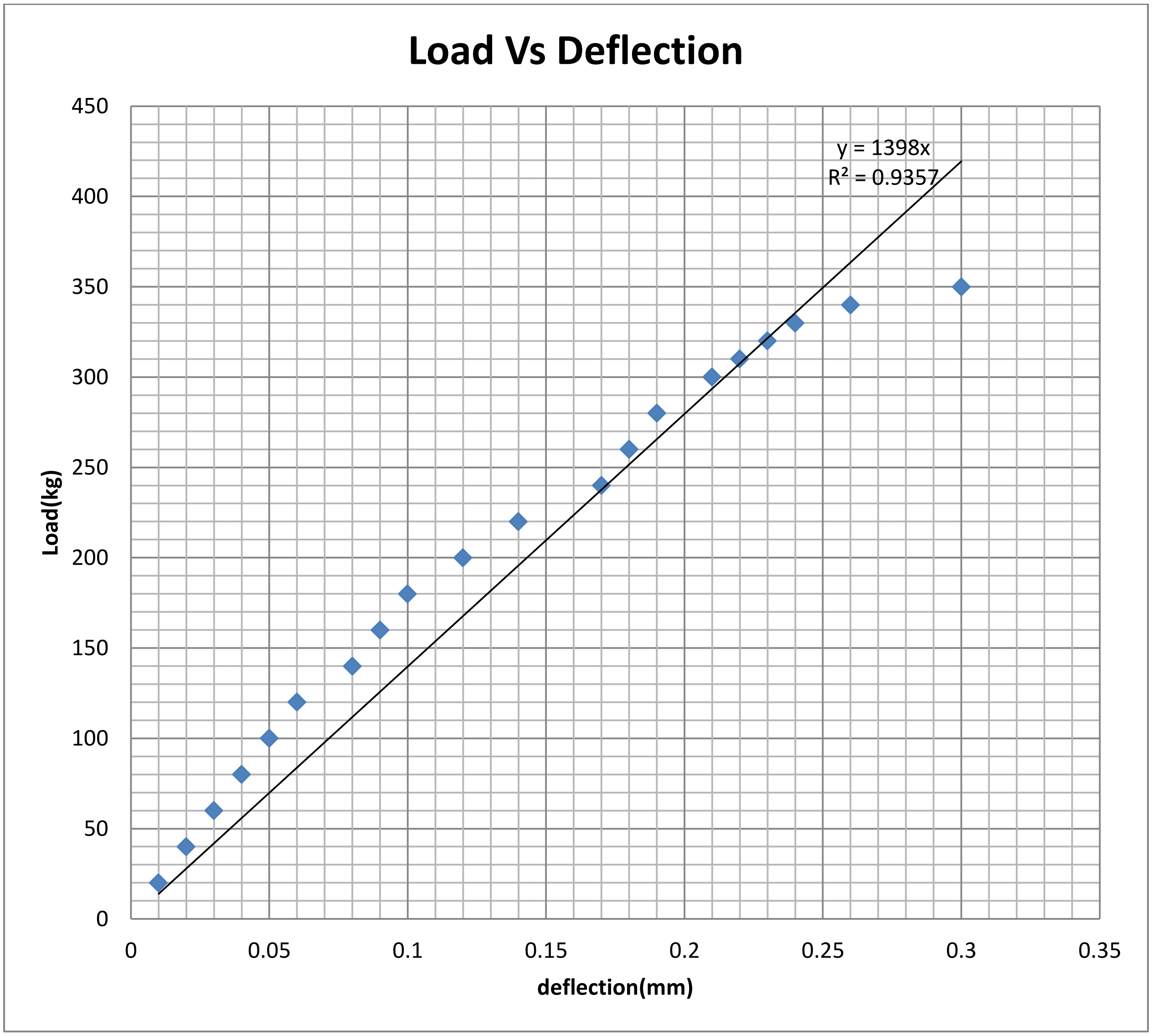


Chart Data:-Table.6.4.

Load(kg)	**Deflection(mm)**
20	0.01
40	0.02
60	0.03
80	0.04
100	0.05
120	0.06
140	0.08
160	0.09
180	0.1
200	0.12
220	0.14
240	0.17
260	0.18
280	0.19
300	0.21
310	0.22
320	0.23
330	0.24
340	0.26
350	0.3

Sample- E

Date of Casting:- 18/1/2011

Opening size:- 0mm dia

Chart-6.5

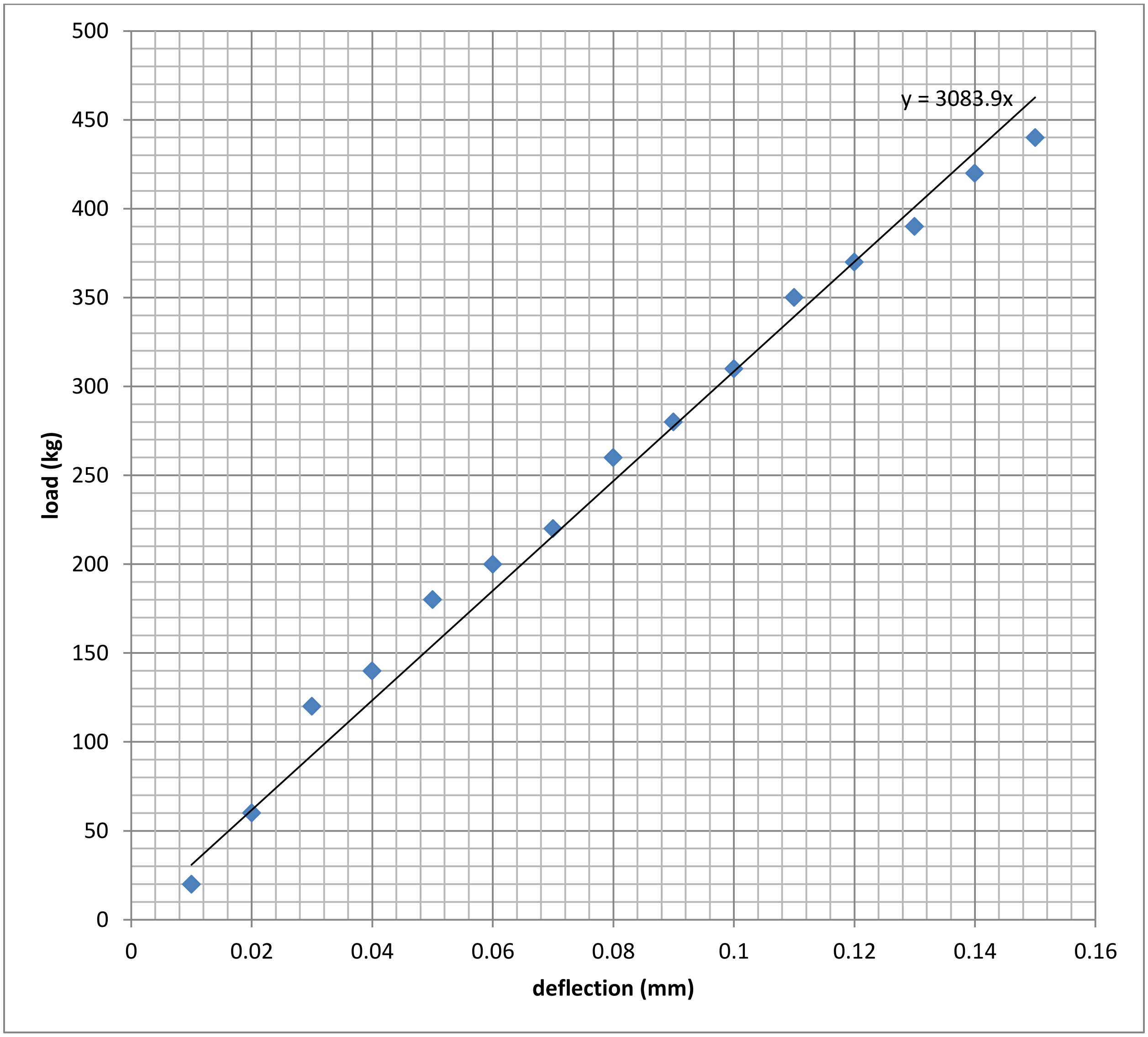


Chart Data:-Table.6.5.

Load(kg)	Deflection(mm)
20	0.01
60	0.02
120	0.03
140	0.04
180	0.05
200	0.06
220	0.07
260	0.08
280	0.09
310	0.1
350	0.11
370	0.12
390	0.13
420	0.14
440	0.15

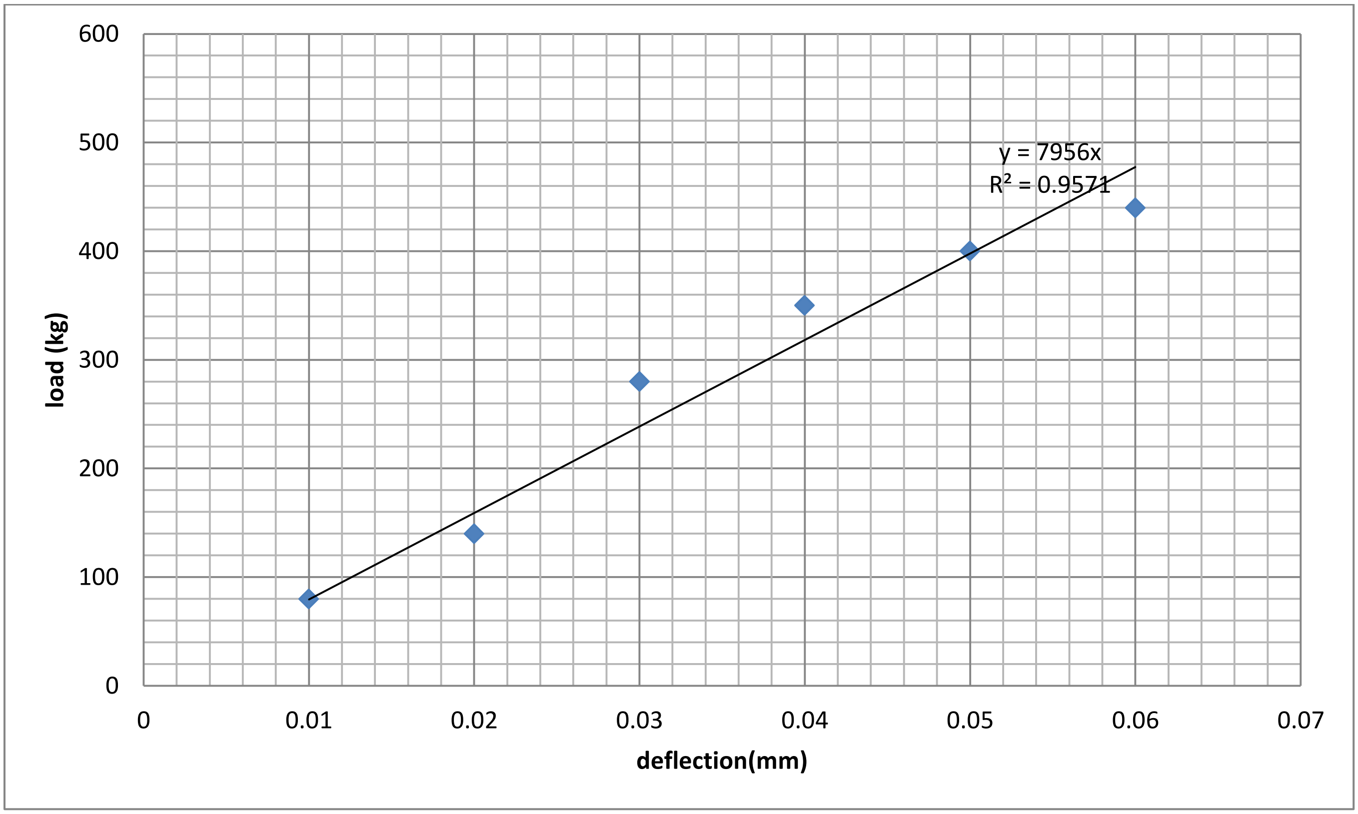
Sample- F (R.C.C Beam)

Date of Casting:- 23/5/2011

opening size:- 63mm dia

Reinf dia:- 2-8Ø((flexural reinf)

Chart-6.6



Load(kg)	Deflection(mm)
80	0.01
140	0.02
280	0.03
350	0.04
400	0.05
440	0.06

Table.6.6

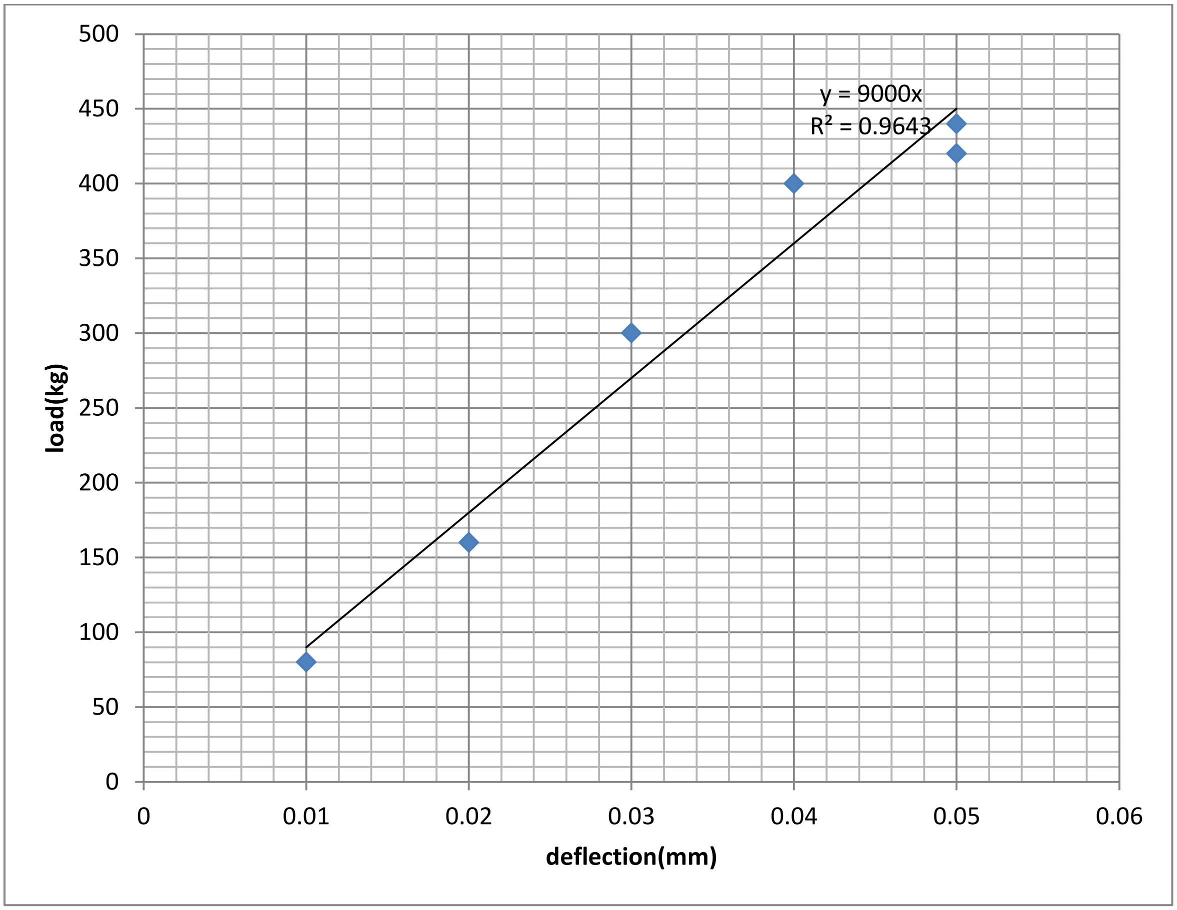
Sample- G (R.C.C Beam)

Date of Casting:- 23/5/2011

opening size:- 63mm dia

Reinf dia:- 2-10Ø(flexural reinf)

Chart-6.7

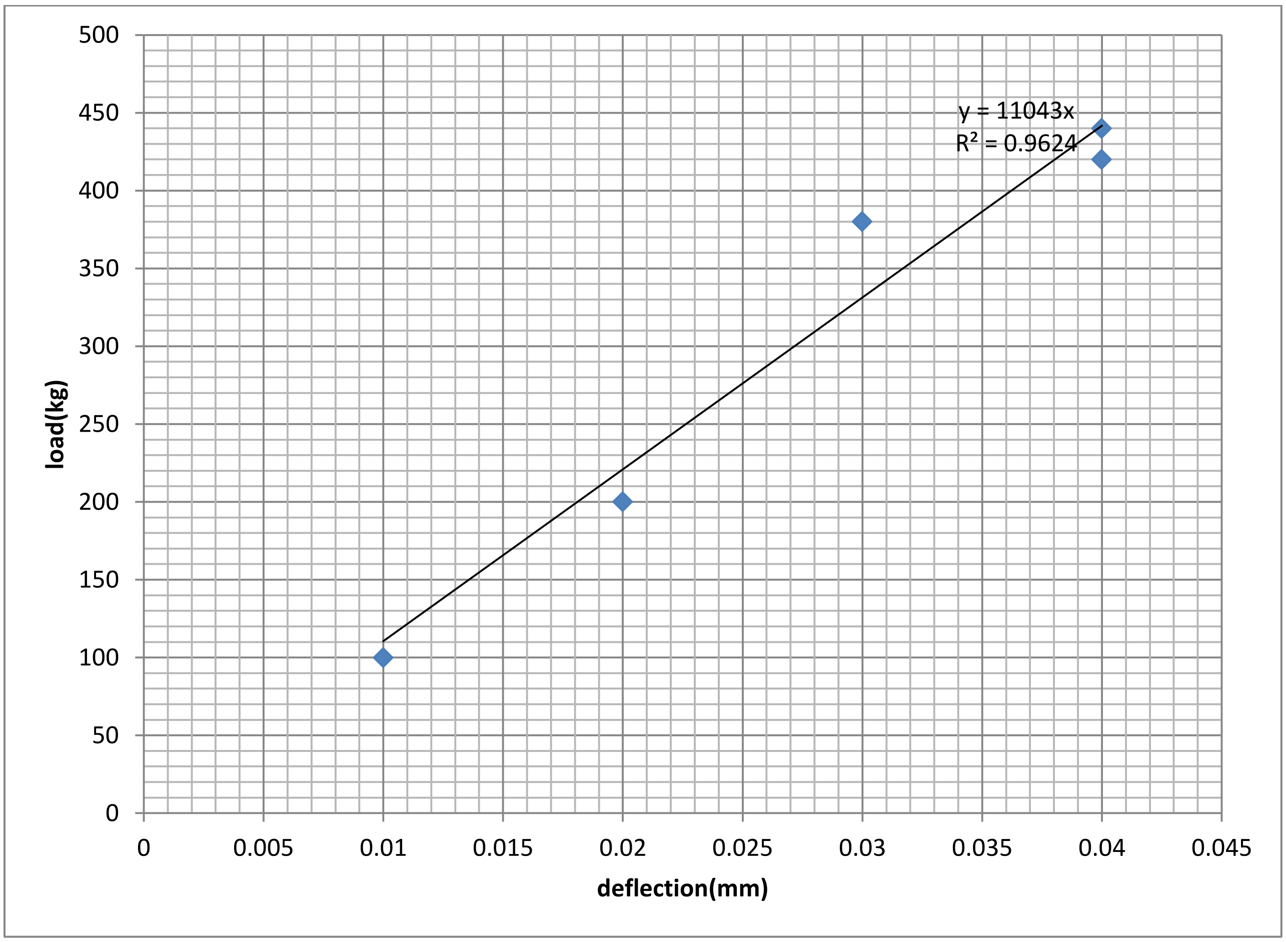


Load(kg)	Deflection(mm)
80	0.01
160	0.02
300	0.03
400	0.04
420	0.05
440	0.05

Table.6.7

Sample-	H (R.C.C Beam)
Date of Casting:-	23/5/2011
opening size:-	63mm dia
Reinf dia:-	2-12Ø(flexural reinf)

Chart-6.8



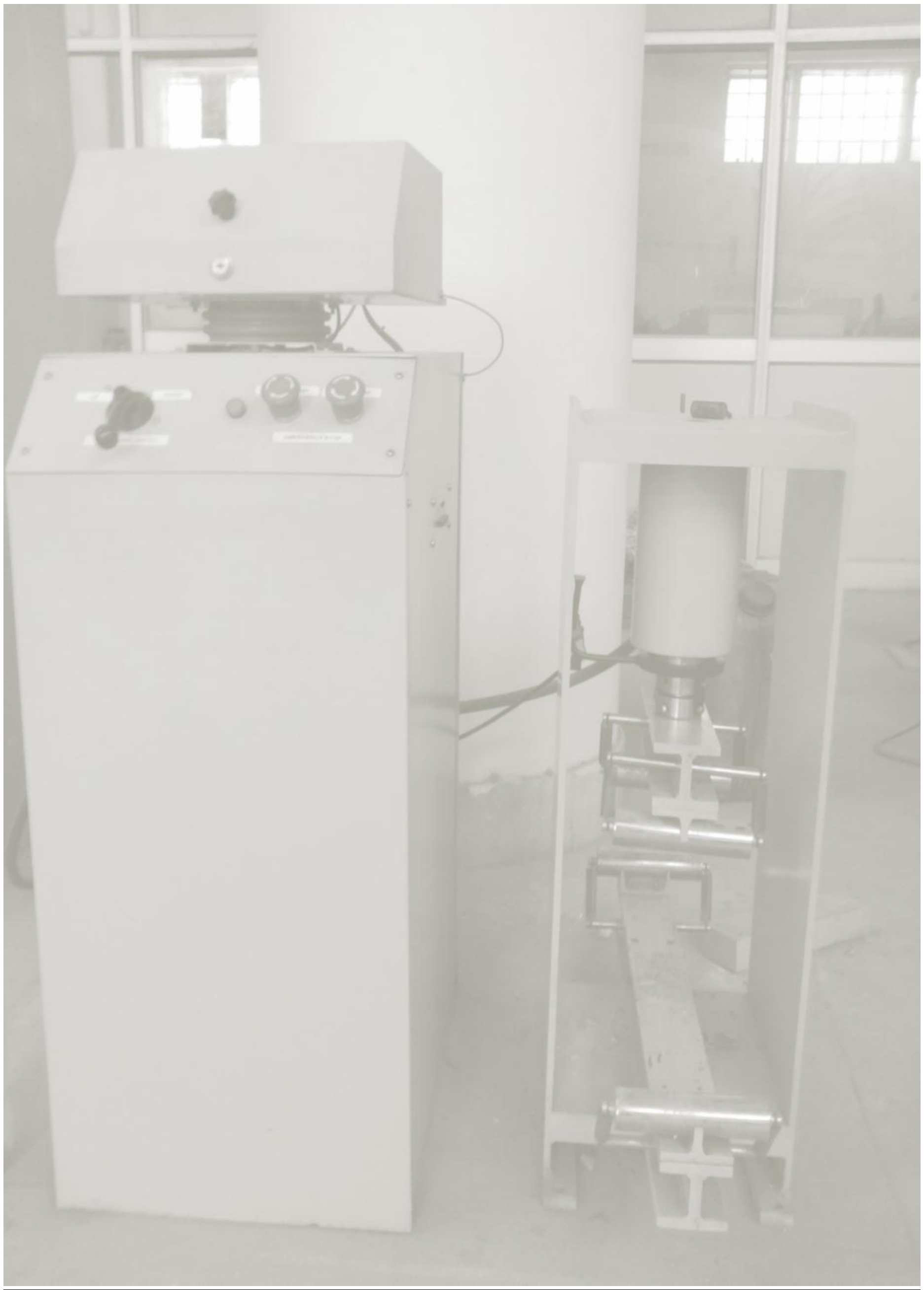
Load(kg)	Deflection(mm)
100	0.01
200	0.02
380	0.03
420	0.04
440	0.04

Table.6.8.

CHAPTER 7

Plain Concrete Beam Test Results (Flexural Strength)

TWO-POINT LOAD TEST OF PLAIN CONCRETE BEAMS

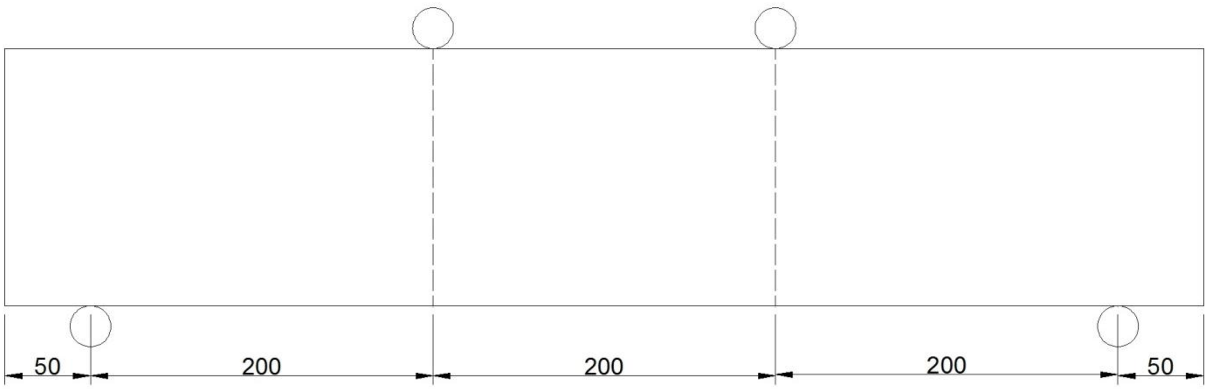


PCC Beam Test Results Summary:-

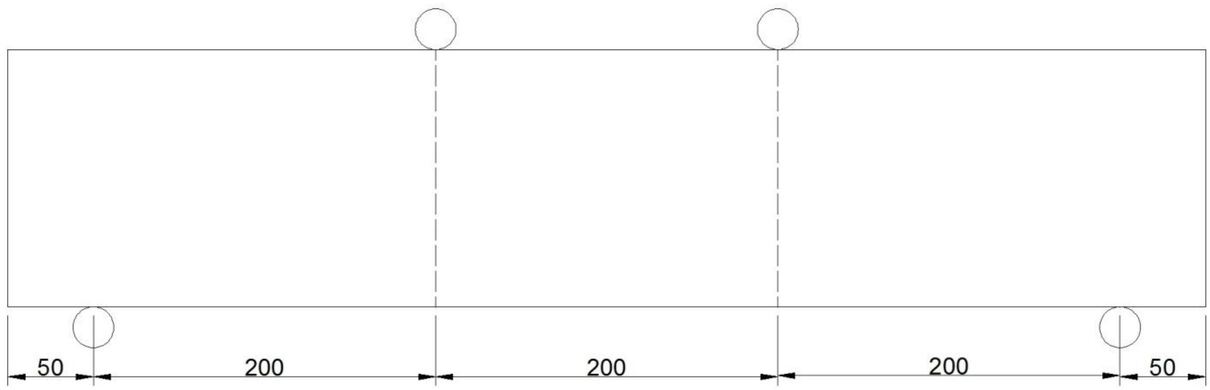
Slno	Opening Dia (mm)	Dist From Edge (mm)	Opening Zone	Load at failure (KN)	Dist of Crack from Nearest Edge (mm)	Failure Zone
1	-	-	-	12.50	230.00	shear
2	-	-	-	12.30	250.00	Flexure
3	-	-	-	12.60	340.00	Flexure
4	-	-	-	11.00	330.00	Flexure
5	-	-	-	12.50	290.00	Flexure
6	-	-	-	14.00	300.00	Flexure
7	-	-	-	12.50	325.00	Flexure
8	-	-	-	13.20	310.00	Flexure
9	50.00	350.00	Flexure	8.50	340.00	Flexure
10	50.00	90.00	shear	11.50	310.00	Flexure
11	50.00	230.00	shear	11.50	240.00	shear
12	50.00	185.00	shear	12.00	230.00	shear
13	40.00	350.00	Flexure	12.00	345.00	Flexure
14	40.00	90.00	shear	12.50	270.00	Flexure
15	40.00	215.00	shear	13.50	235.00	shear
16	40.00	230.00	shear	10.00	240.00	shear
17	63.00	350.00	Flexure	5.00	350.00	Flexure
18	63.00	95.00	shear	12.60	180.00	shear
19	63.00	120.00	shear	11.00	130.00	shear
20	63.00	200.00	shear	9.50	230.00	shear
21	75.00	350.00	Flexure	3.00	350.00	Flexure
22	75.00	90.00	shear	4.50	90.00	shear
23	75.00	200.00	shear	8.50	200.00	shear

Table-7.1.

Beam No:-	1
Grade of Concrete:-	M30
Opening Diameter (mm):-	NIL
Opening Location from edge (mm):-	NIL
Failure Load (KN):-	12.5
Location of failure from edge (mm):-	230
Zone of Failure:-	Shear



Beam No:-	2
Grade of Concrete:-	M30
Opening Diameter (mm):-	NIL
Opening Location from edge (mm):-	NIL
Failure Load (KN):-	12.5
Location of failure from edge (mm):-	250
Zone of Failure:-	Flexure



Beam No:- 3

Grade of Concrete:- M30

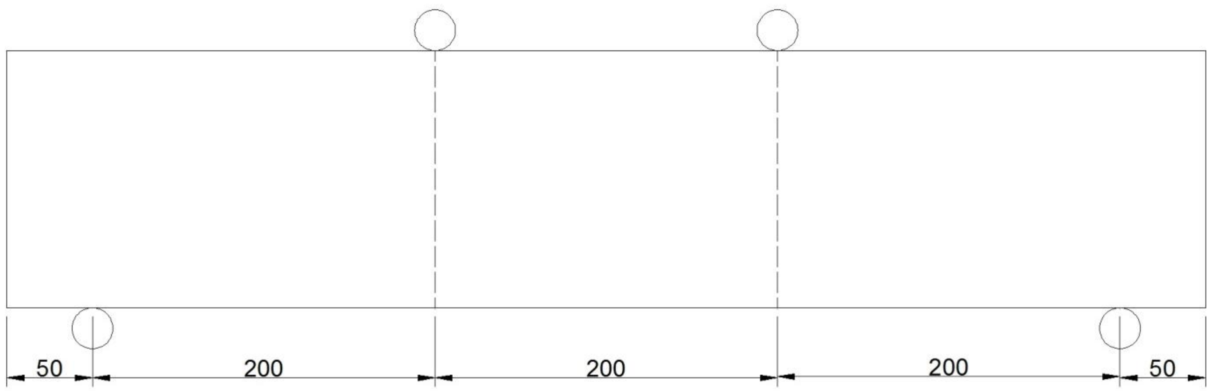
Opening Diameter (mm):- NIL

Opening Location from edge (mm):- NIL

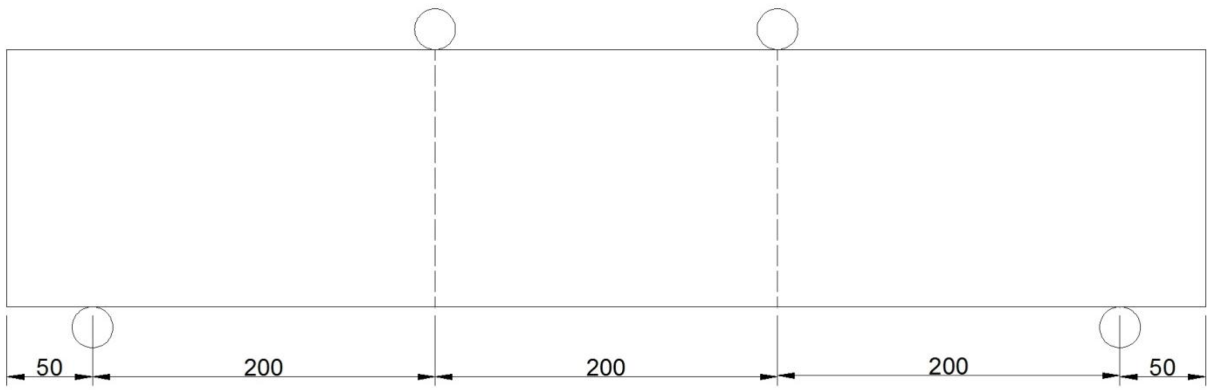
Failure Load (KN):- 12.6

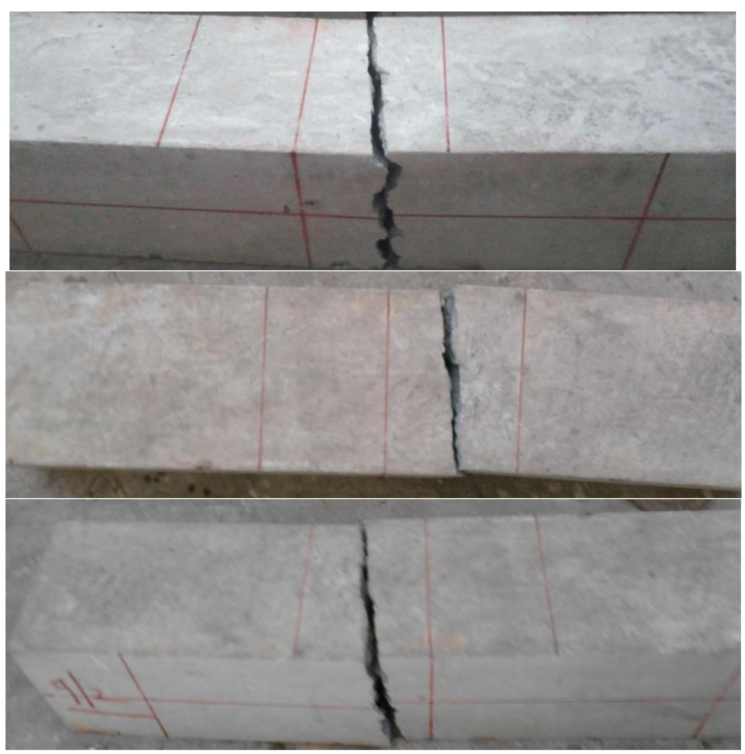
Location of failure from edge (mm):- 340

Zone of Failure:- Flexure

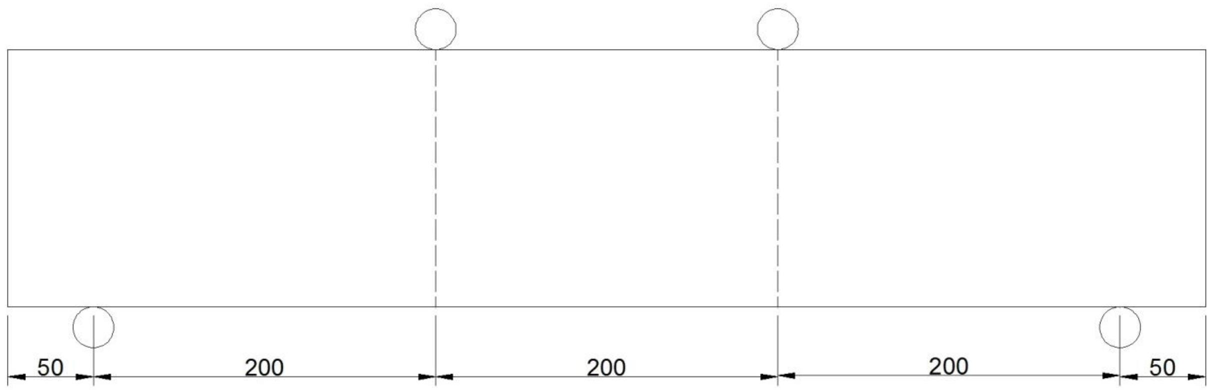


Beam No:-	4
Grade of Concrete:-	M30
Opening Diameter (mm):-	NIL
Opening Location from edge (mm):-	NIL
Failure Load (KN):-	11.0
Location of failure from edge (mm):-	330
Zone of Failure:-	Flexure

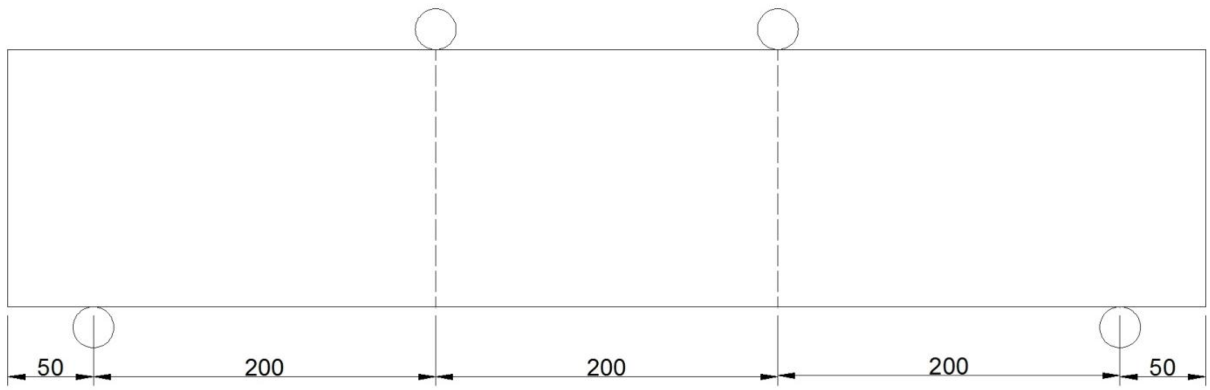




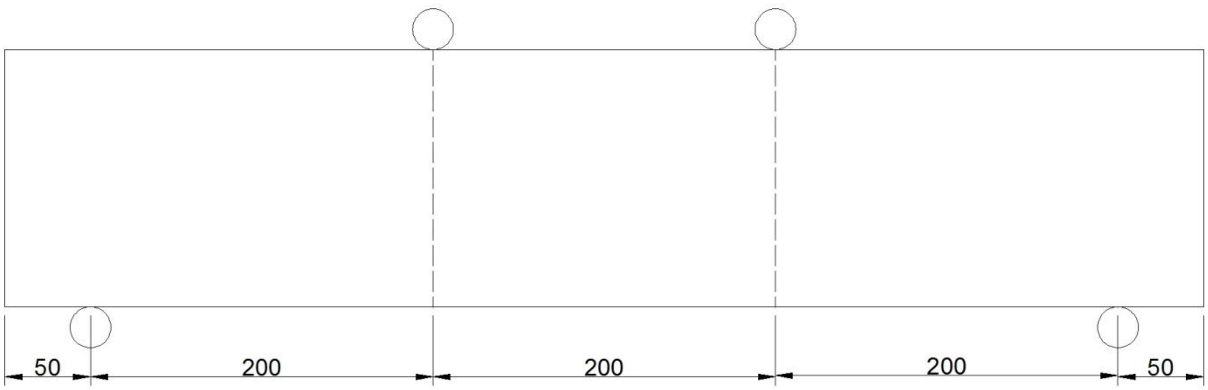
Beam No:-	5
Grade of Concrete:-	M30
Opening Diameter (mm):-	NIL
Opening Location from edge (mm):-	NIL
Failure Load (KN):-	12.5
Location of failure from edge (mm):-	290
Zone of Failure:-	Flexure



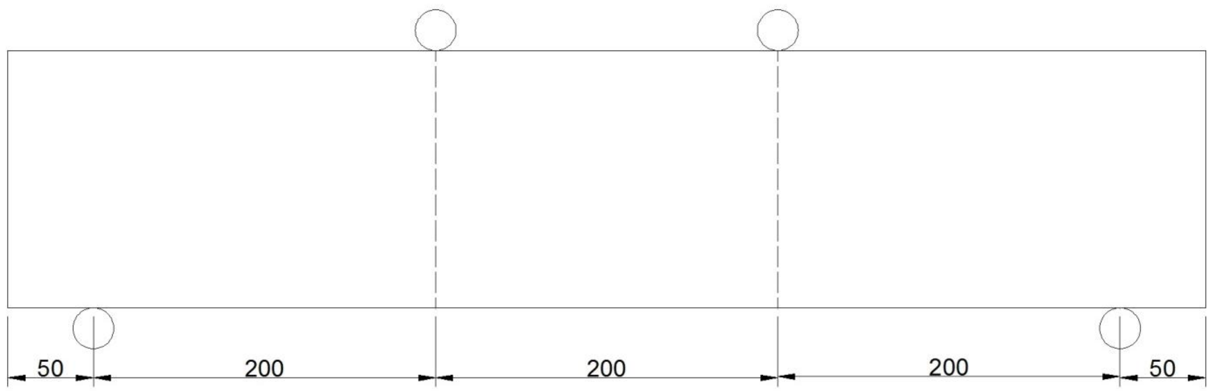
Beam No:-	6
Grade of Concrete:-	M30
Opening Diameter (mm):-	NIL
Opening Location from edge (mm):-	NIL
Failure Load (KN):-	14.0
Location of failure from edge (mm):-	300
Zone of Failure:-	Flexure



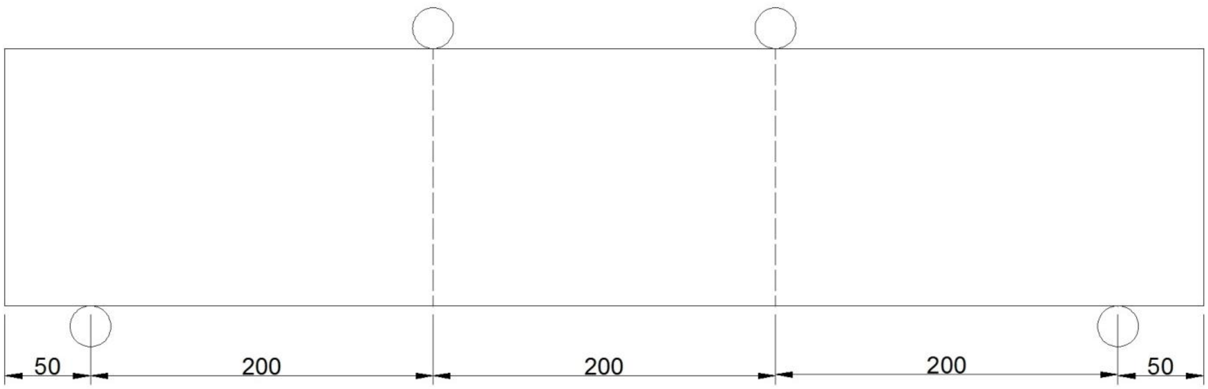
Beam No:-	7
Grade of Concrete:-	M30
Opening Diameter (mm):-	NIL
Opening Location from edge (mm):-	NIL
Failure Load (KN):-	12.5
Location of failure from edge (mm):-	325
Zone of Failure:-	Flexure

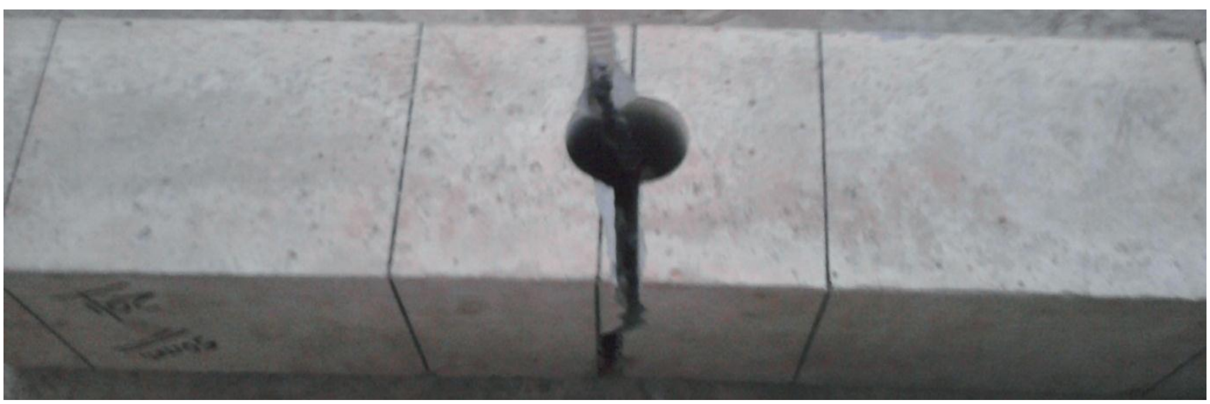


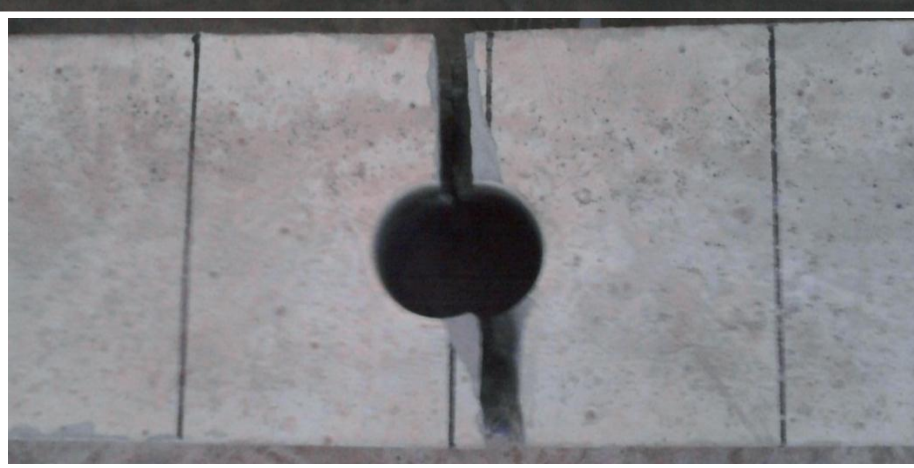
Beam No:-	8
Grade of Concrete:-	M30
Opening Diameter (mm):-	NIL
Opening Location from edge (mm):-	NIL
Failure Load (KN):-	13.2
Location of failure from edge (mm):-	310
Zone of Failure:-	Flexure



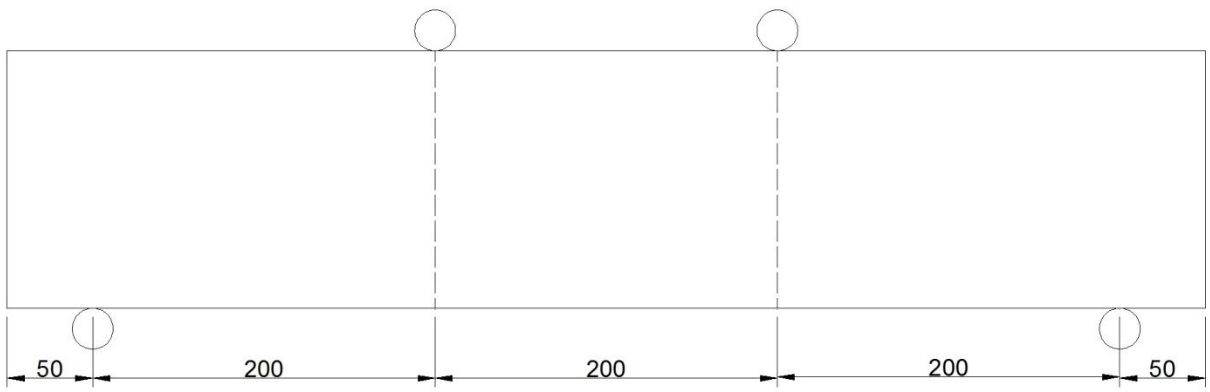
Beam No:-	9
Grade of Concrete:-	M30
Opening Diameter (mm):-	50
Opening Location from edge (mm):-	Centre
Failure Load (KN):-	11.5
Location of failure from edge (mm):-	340
Zone of Failure:-	Flexure

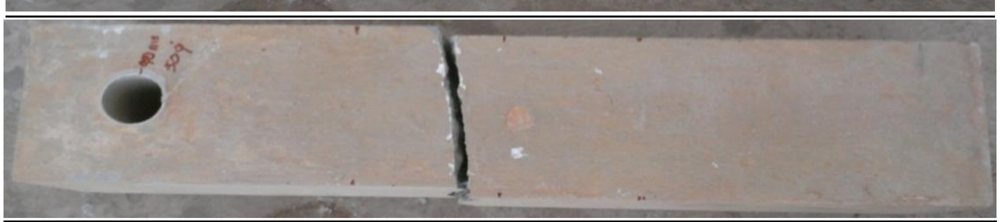




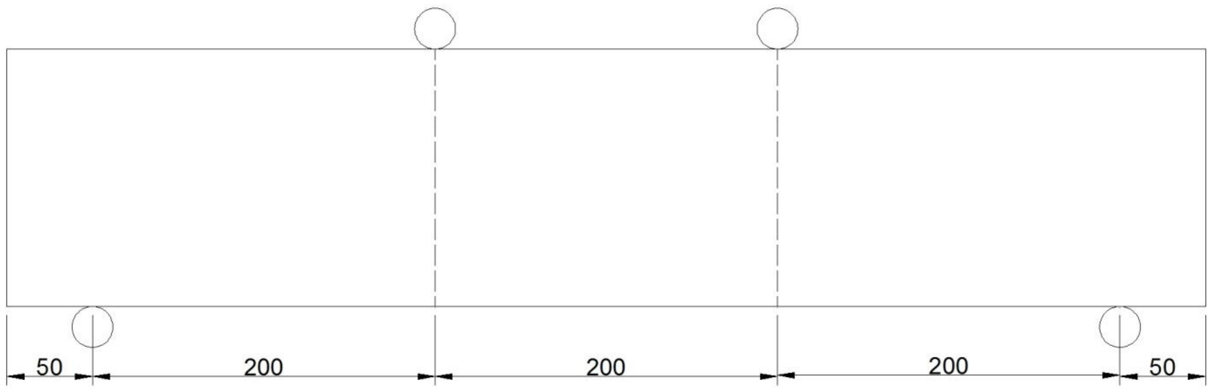


Beam No:-	10
Grade of Concrete:-	M30
Opening Diameter (mm):-	50
Opening Location from edge (mm):-	90
Failure Load (KN):-	11.5
Location of failure from edge (mm):-	310
Zone:-	Flexure





Beam No:-	11
Grade of Concrete:-	M30
Opening Diameter (mm):-	50
Opening Location from edge (mm):-	230
Failure Load (KN):-	11.5
Location of failure from edge (mm):-	240
Zone:-	Shear



Beam No:- 12

Grade of Concrete:- M30

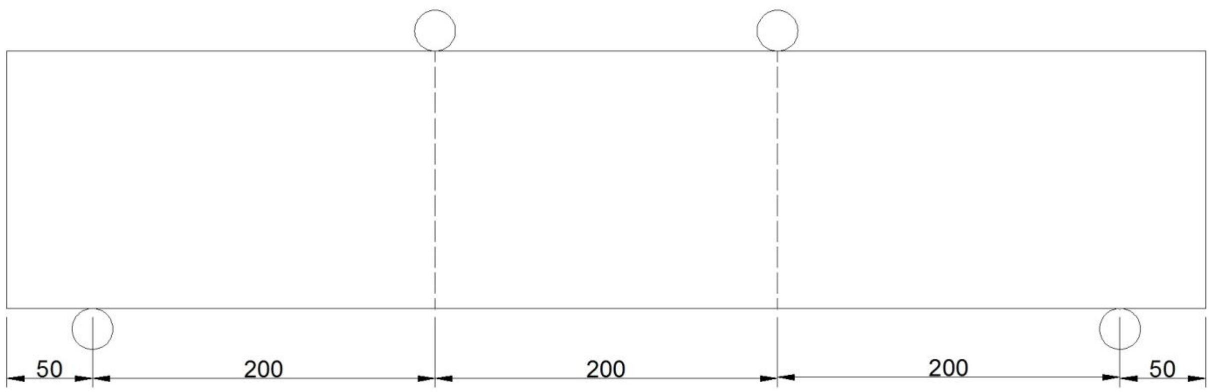
Opening Diameter (mm):- 50

Opening Location from edge (mm):- 185

Failure Load (KN):- 12.0

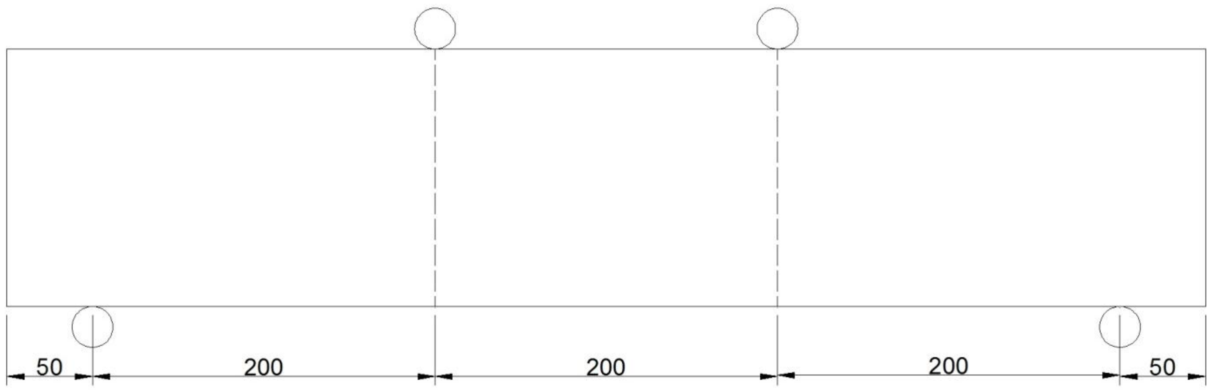
Location of failure from edge (mm):- 240

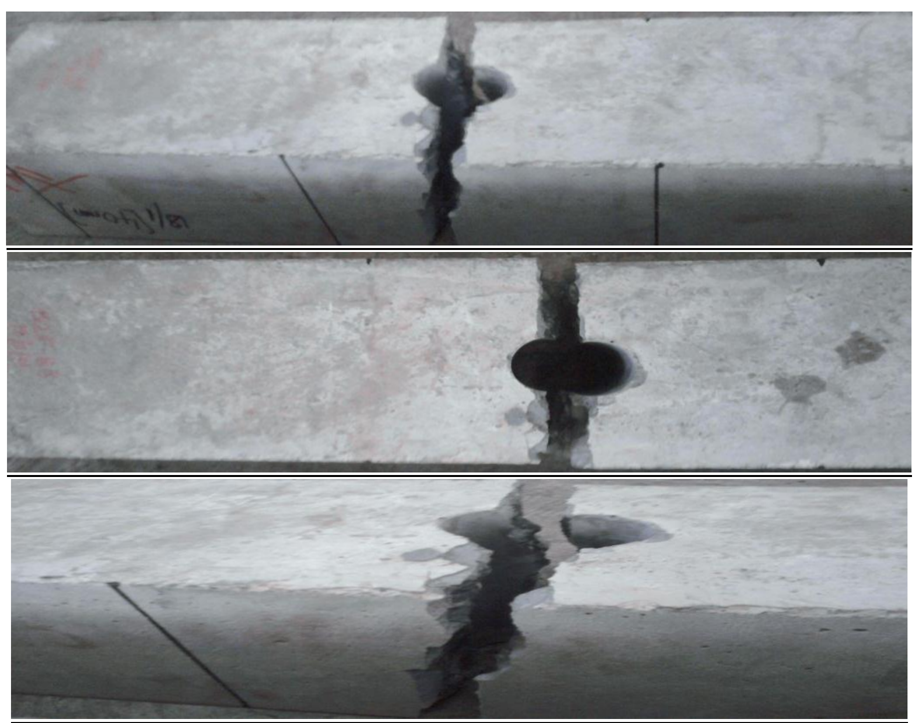
Zone:- Shear



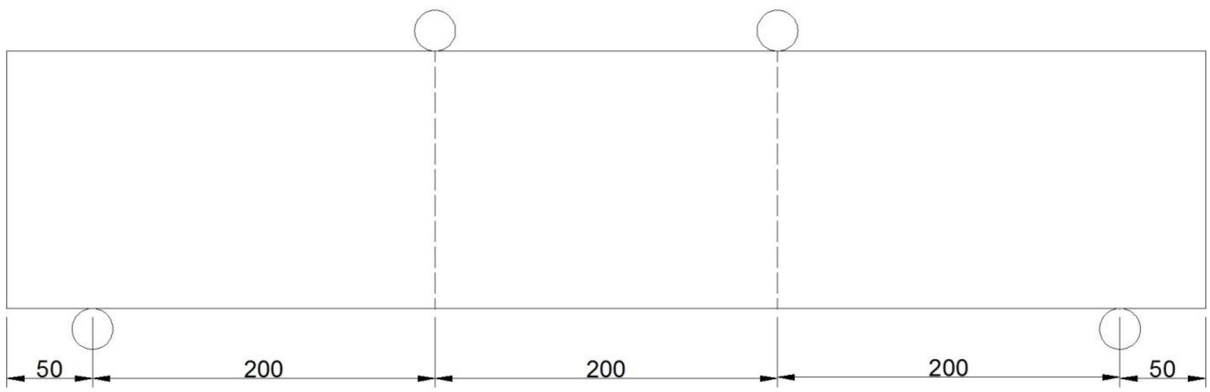


Beam No:-	13
Grade of Concrete:-	M30
Opening Diameter (mm):-	40
Opening Location from edge (mm):-	Nil
Failure Load (KN):-	12.0
Location of failure from edge (mm):-	345
Zone:-	Flexure





Beam No:-	14
Grade of Concrete:-	M30
Opening Diameter (mm):-	40
Opening Location from edge (mm):-	90
Failure Load (KN):-	12.5
Location of failure from edge (mm):-	270
Zone:-	Flexure



Beam No:- 15

Grade of Concrete:- M30

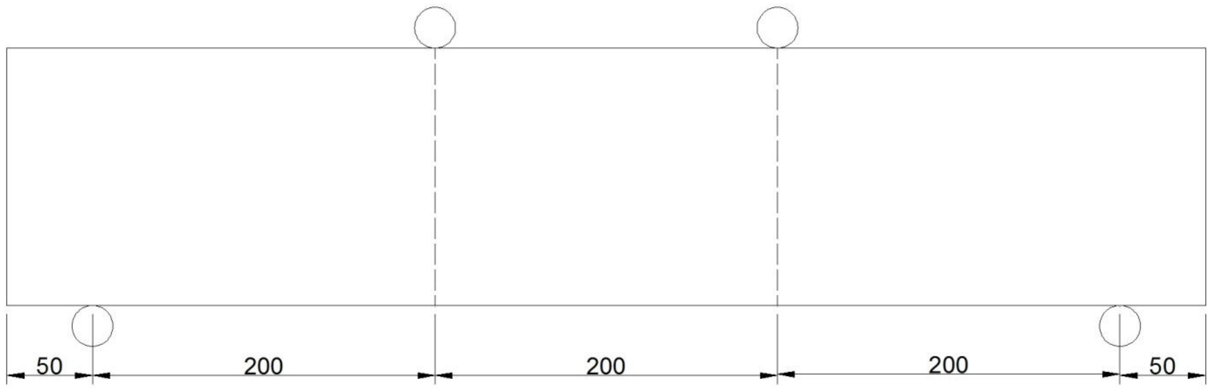
Opening Diameter (mm):- 40

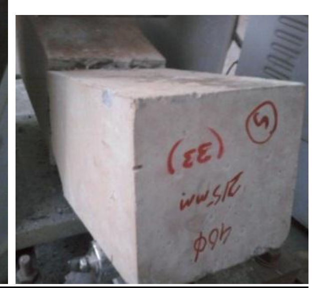
Opening Location from edge (mm):- 215

Failure Load (KN):- 13.5

Location of failure from edge (mm):- 235

Zone:- Shear



Beam No:- 16

Grade of Concrete:- M30

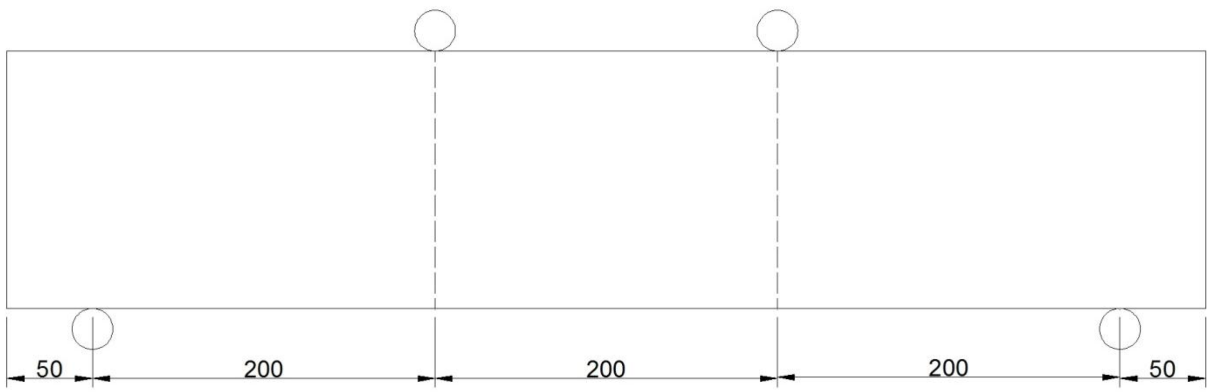
Opening Diameter (mm):- 40

Opening Location from edge (mm):- 230

Failure Load (KN):- 10.0

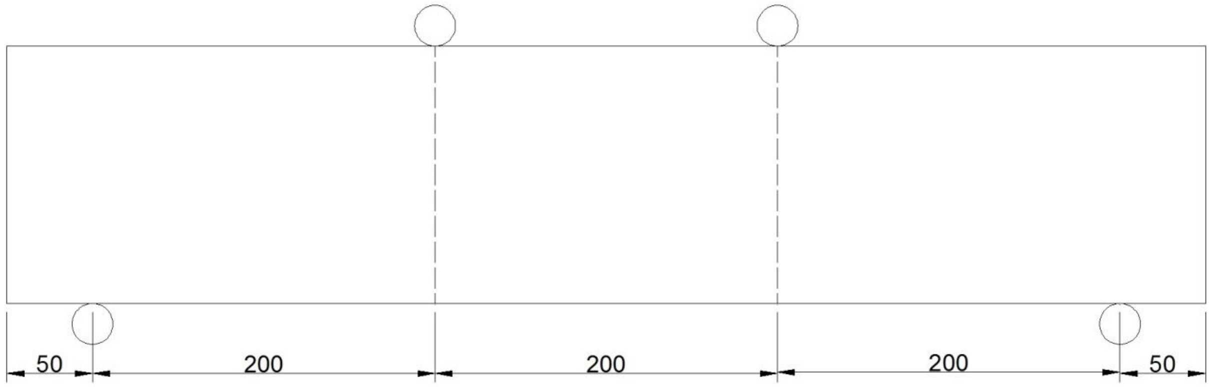
Location of failure from edge (mm):- 240

Zone:- Shear






Beam No:-	17
Grade of Concrete:-	M30
Opening Diameter (mm):-	63
Opening Location from edge (mm):-	Centre
Failure Load (KN):-	5.0
Location of failure from edge (mm):-	350
Zone:-	Flexure



Beam No:- 18

Grade of Concrete:- M30

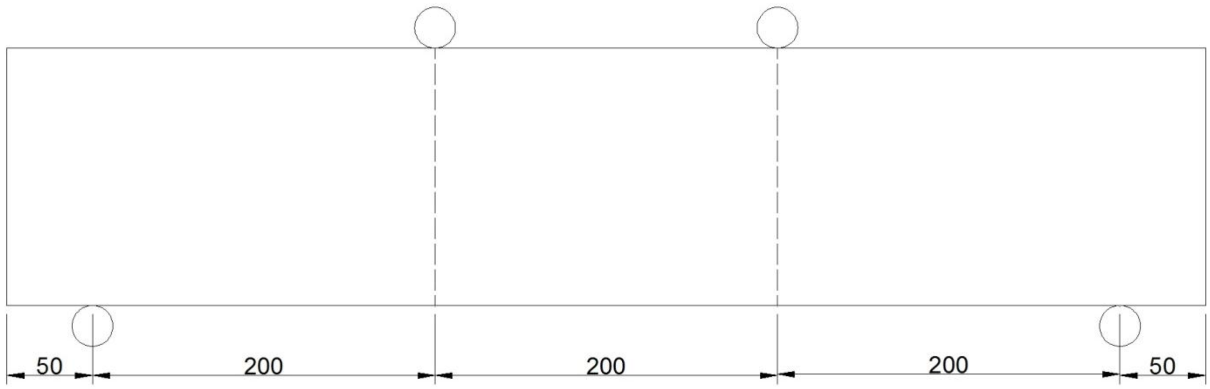
Opening Diameter (mm):- 63

Opening Location from edge (mm):- 95

Failure Load (KN):- 12.6

Location of failure from edge (mm):- 180

Zone of Failure:- Shear





Beam No:- 19

Grade of Concrete:- M30

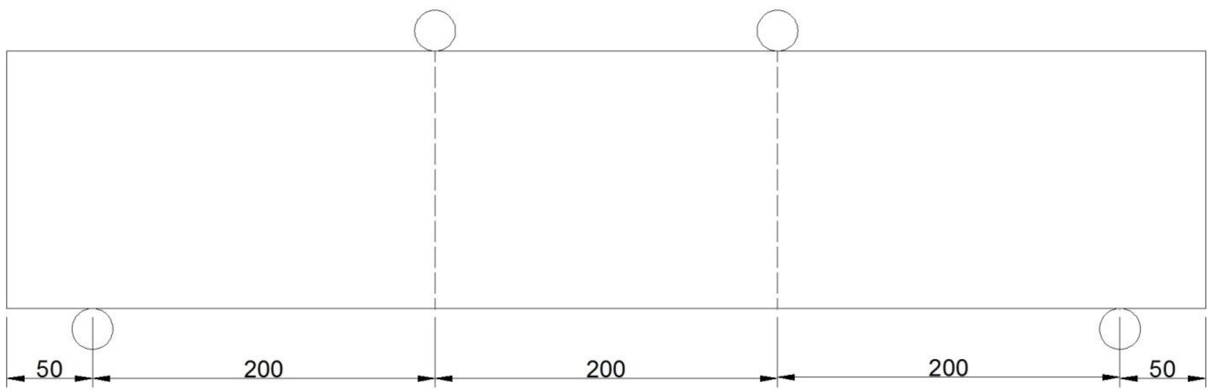
Opening Diameter (mm):- 63

Opening Location from edge (mm):- 120

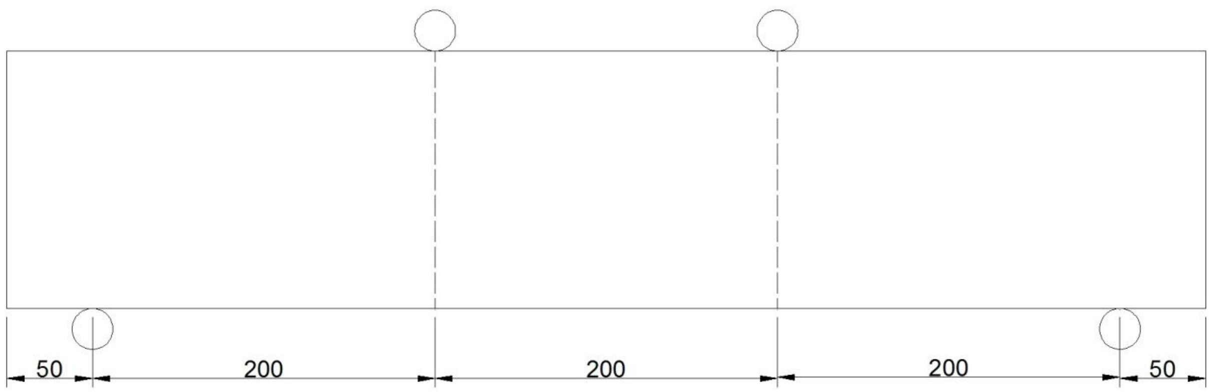
Failure Load (KN):- 11.0

Location of failure from edge (mm):- 130

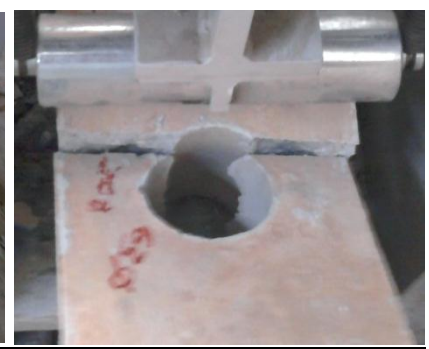
Zone of Failure:- Shear



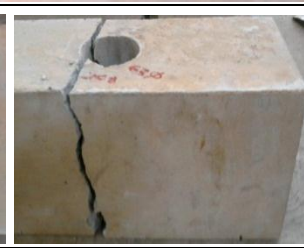
Beam No:-	20
Grade of Concrete:-	M30
Opening Diameter (mm):-	63
Opening Location from edge (mm):-	200
Failure Load (KN):-	9.50
Location of failure from edge (mm):-	230
Zone of Failure:-	Shear



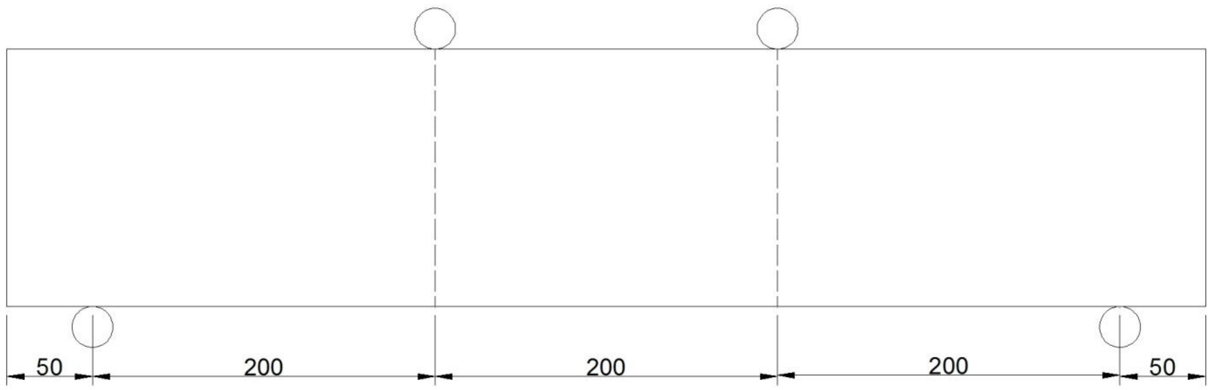








Beam No:-	21
Grade of Concrete:-	M30
Opening Diameter (mm):-	75
Opening Location from edge (mm):-	350
Failure Load (KN):-	2.00
Location of failure from edge (mm):-	350
Zone of Failure:-	Flexure



Beam No:- 22

Grade of Concrete:- M30

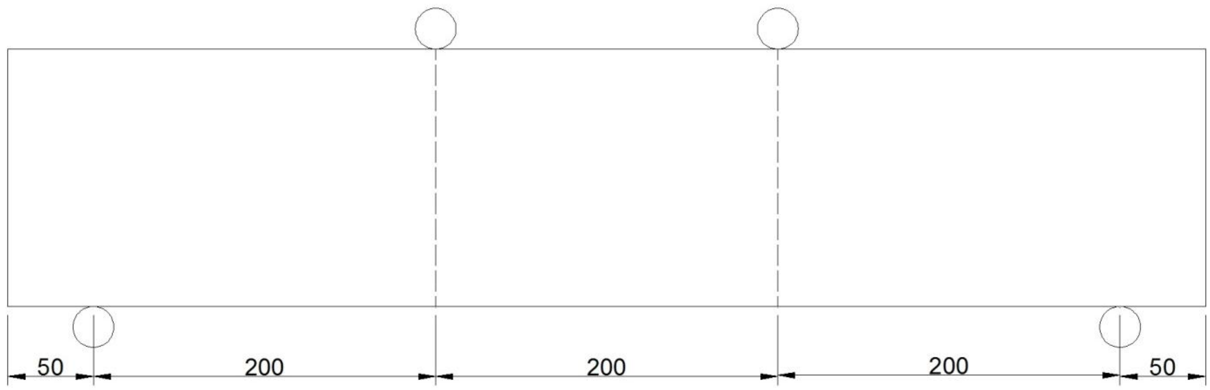
Opening Diameter (mm):- 75

Opening Location from edge (mm):- 90

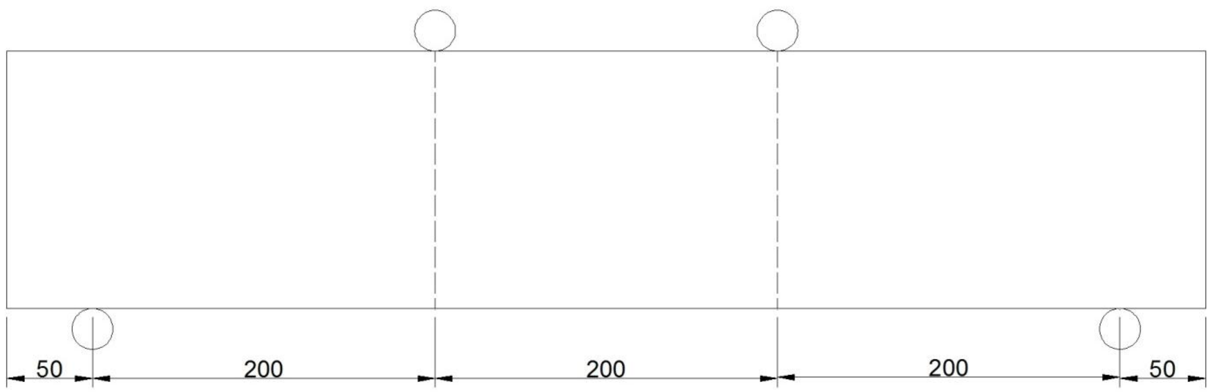
Failure Load (KN):- 4.50

Location of failure from edge (mm):- 120

Zone of Failure:- Shear



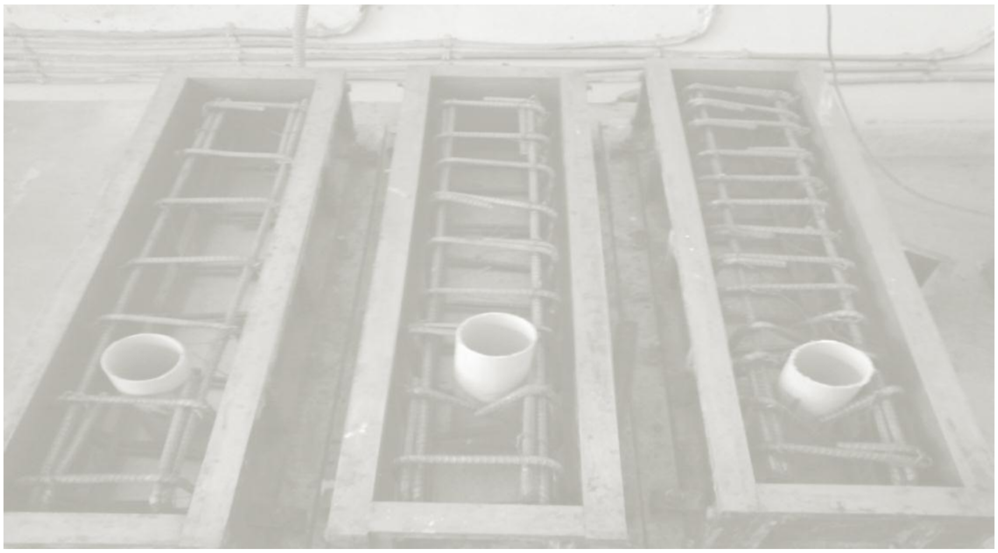
Beam No:-	23
Grade of Concrete:-	M30
Opening Diameter (mm):-	75
Opening Location from edge (mm):-	200
Failure Load (KN):-	8.50
Location of failure from edge (mm):-	200
Zone of Failure:-	Shear

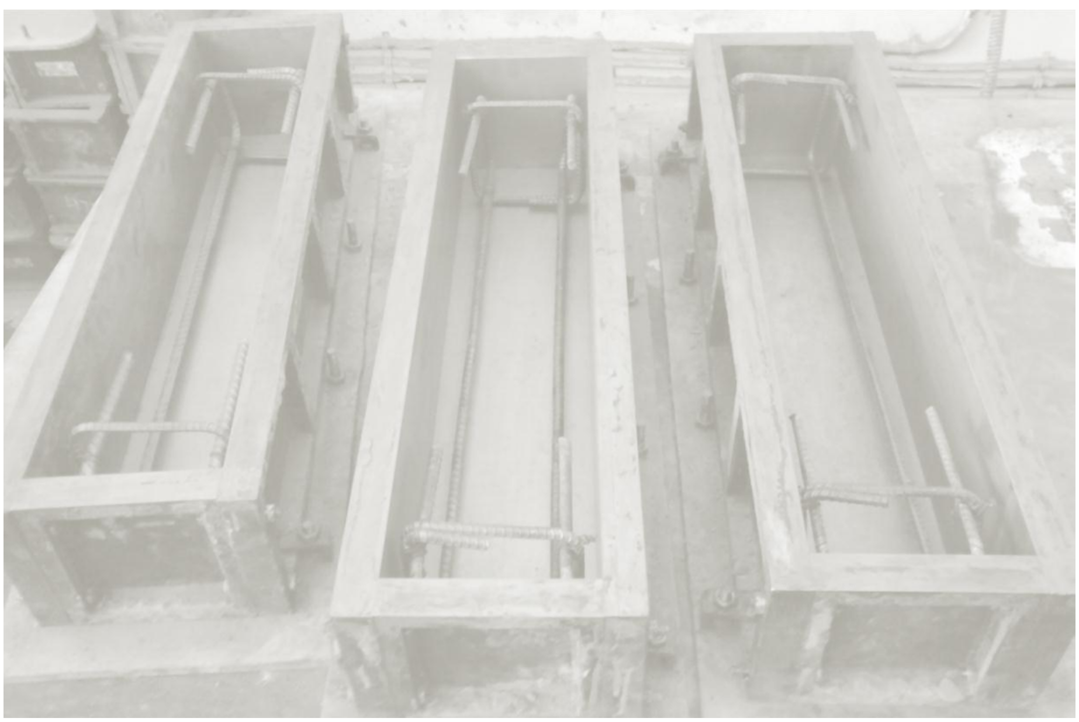


CHAPTER 8

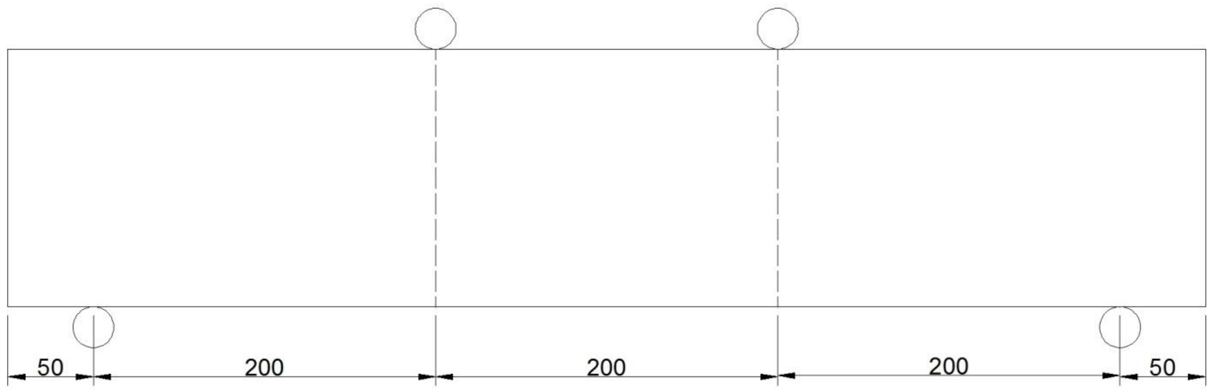
Steel Reinforced Concrete Beam Test Results

TWO-POINT LOAD TEST OF STEEL REINFORCED CONCRETE BEAMS





R.C.C Beam No:-	1
Concrete Strength:-	28.78N/mm^2
Tension Reinf:-	2-8mmØ
Top Reinf:-	NIL
Shear Reinf:-	NIL
Opening Diameter (mm):-	63mm
Opening dist from edge (mm):-	350
Failure Load (KN):-	66KN (2xP)
Zone of Fail ure:-	FLEXURE



R.C.C Beam No:- 2

Concrete Strength:- 28.78N/mm^2

Tension Reinf:- 2-10mmØ

Top Reinf:- NIL

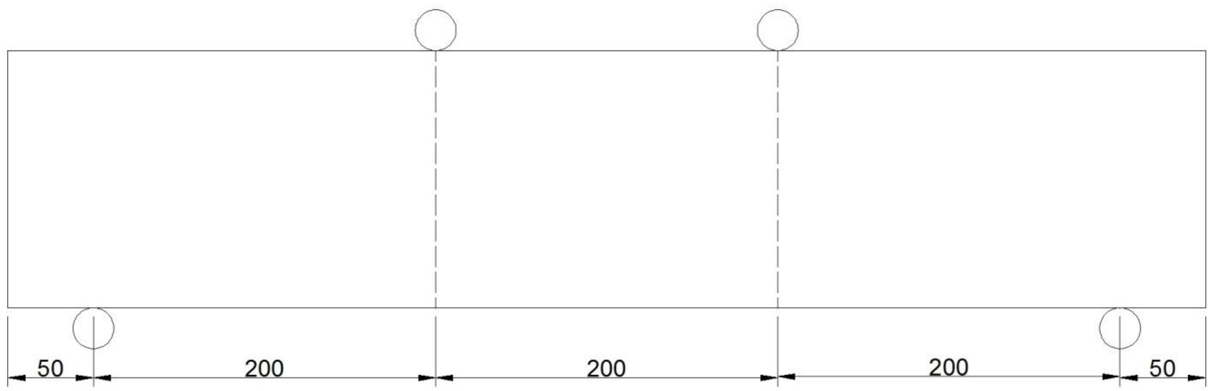
Shear Reinf:- NIL

Opening Diameter (mm):- 63mm

Opening dist from edge (mm):- 350

Failure Load (KN):- 79.5KN (2xP)

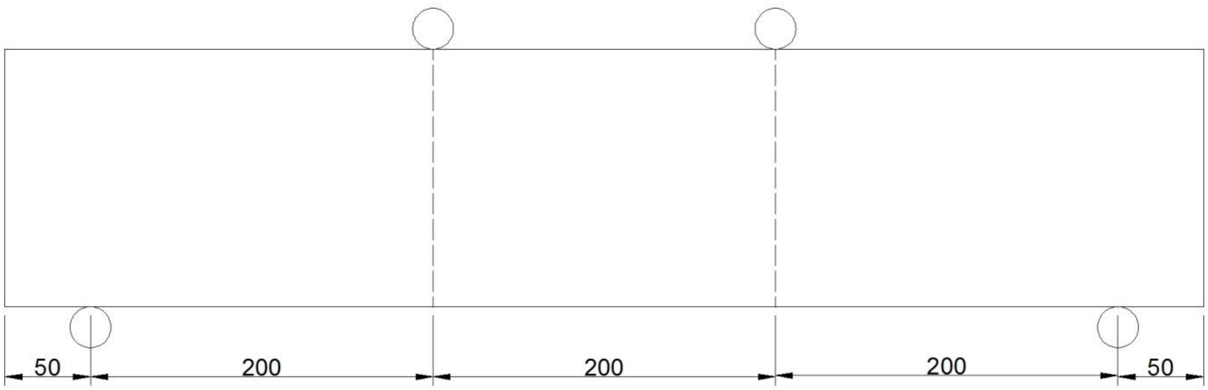
Zone of Failure:- FLEXURE




23|5
2-10ϕ

23|5
2-10ϕ

R.C.C Beam No:-	3
Concrete Strength:-	28.78N/mm^2
Tension Reinf:-	2-12mmØ
Top Reinf:-	NIL
Shear Reinf:-	NIL
Opening Diameter (mm):-	63mm
Opening dist from edge (mm):-	350
Failure Load (KN):-	No-Result
Zone of Failure:-	No-Result



R.C.C Beam No:- 4

Concrete Strength:- 27.73N/mm^2

Tension Reinf:- 2-8mmØ

Top Reinf:- NIL

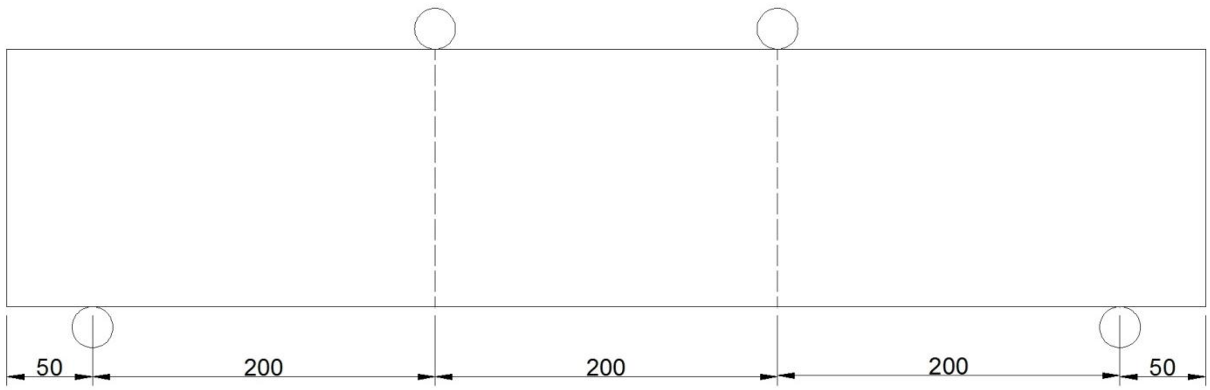
Shear Reinf:- NIL

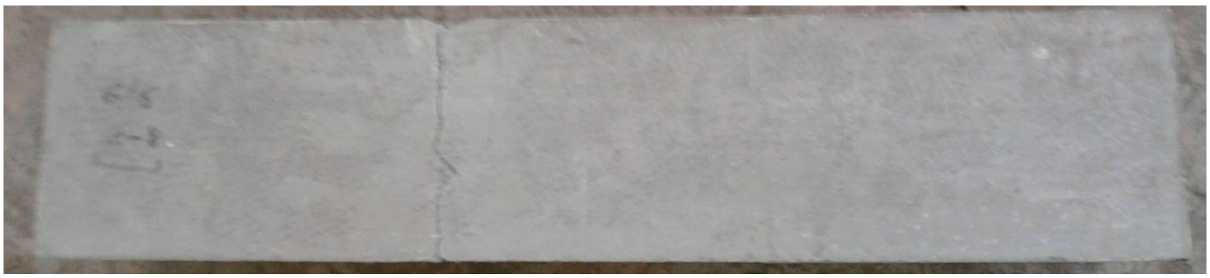
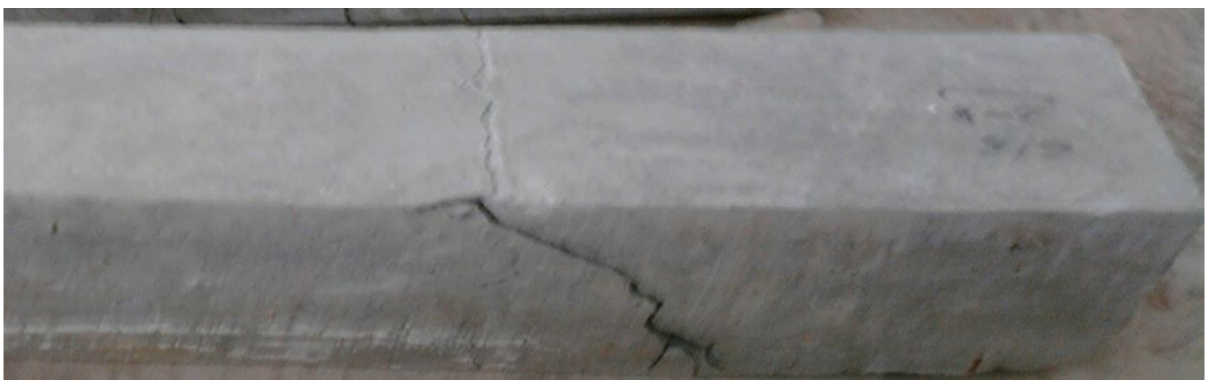
Opening Diameter (mm):- NIL

Opening dist from edge (mm):- NIL

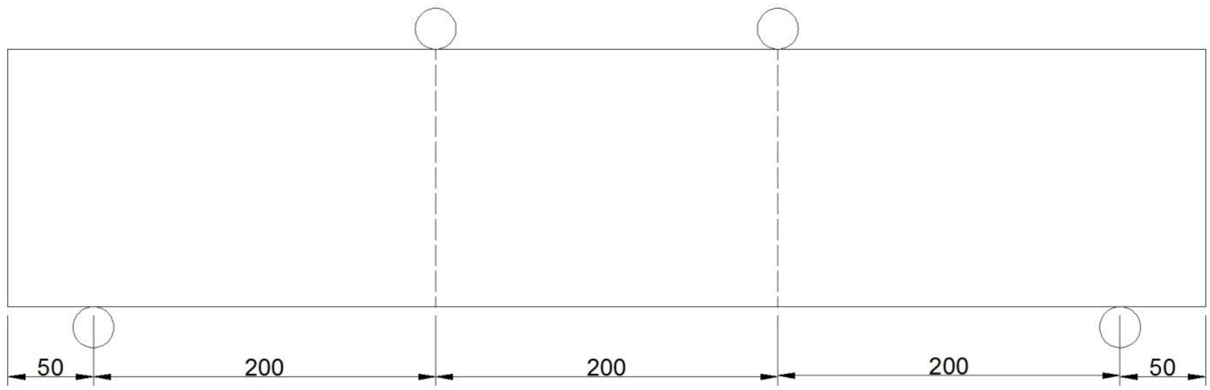
Failure Load (KN):- 75.00KN (2xP)

Zone of Failure:- SHEAR

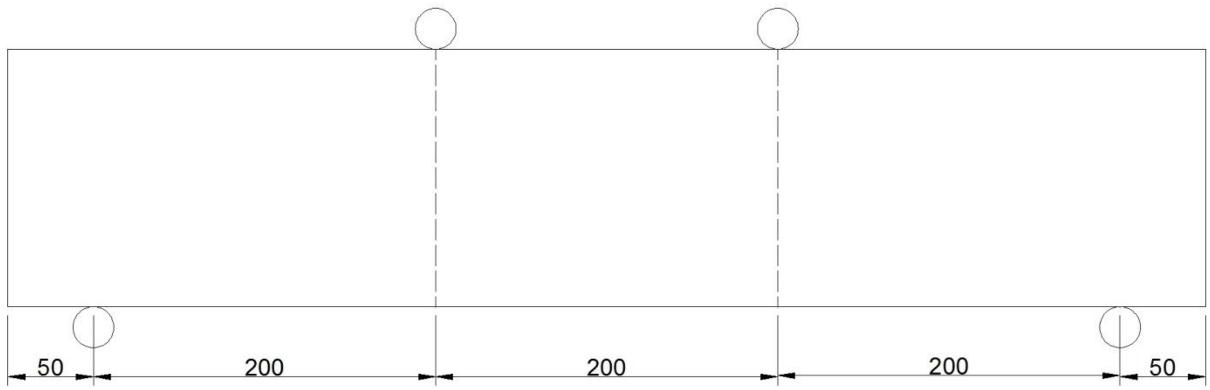


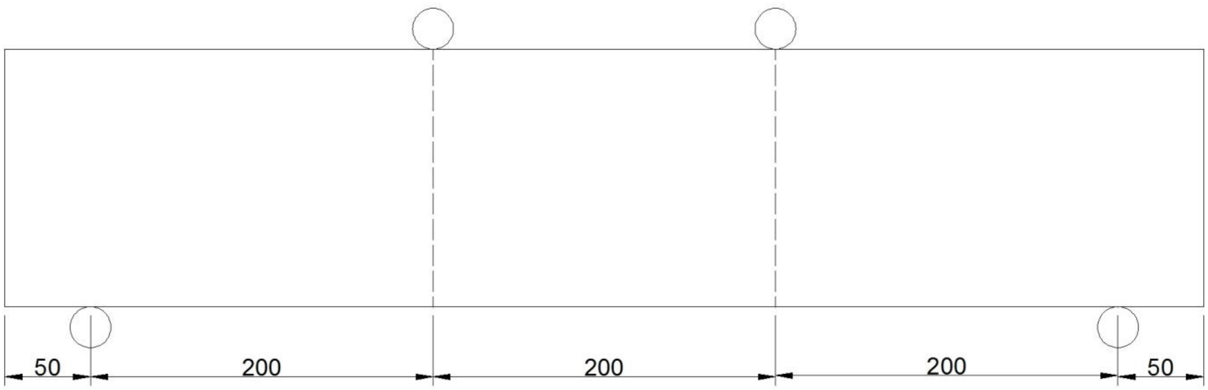
R.C.C Beam No:-	5
Concrete Strength:-	27.73N/mm^2
Tension Reinf:-	2-10mmØ
Top Reinf:-	NIL
Shear Reinf:-	NIL
Opening Diameter (mm):-	NIL
Opening dist from edge (mm):-	NIL
Failure Load (KN):-	86.00KN (2xP)
Zone of Failure:-	SHEAR



R.C.C Beam No:-	6
Concrete Strength:-	27.73N/mm^2
Tension Reinf:-	2-10mmØ
Top Reinf:-	NIL
Shear Reinf:-	NIL
Opening Diameter (mm):-	NIL
Opening dist from edge (mm):-	NIL
Failure Load (KN):-	NO-RESULT
Zone of Failure:-	NO-RESULT

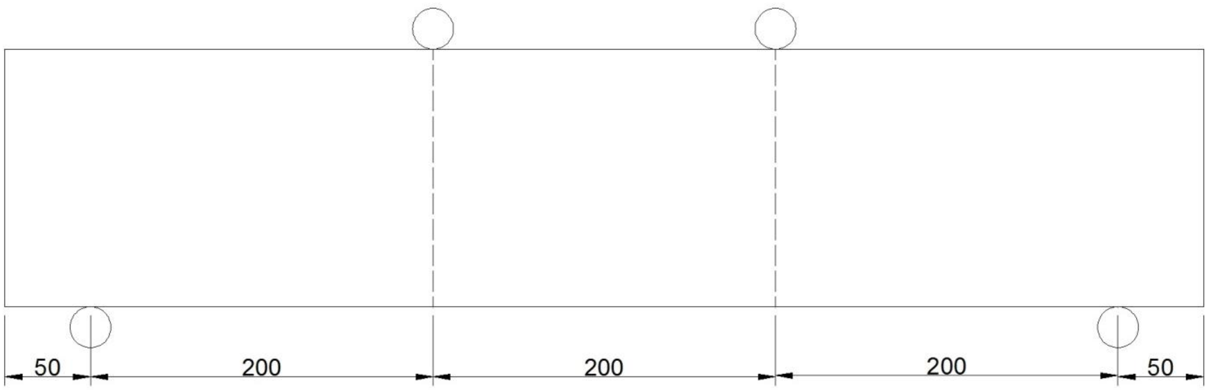


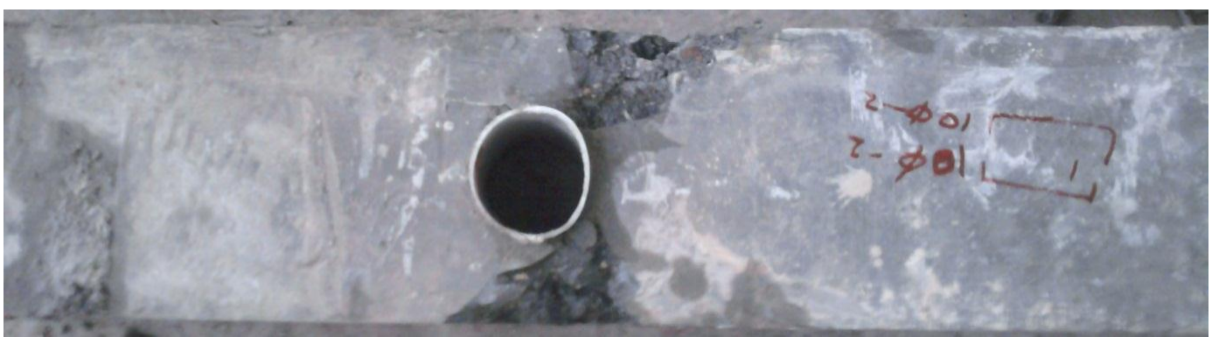
R.C.C Beam No:-	7
Concrete Strength:-	29.20N/mm^2
Tension Reinf:-	2-10mmØ
Top Reinf:-	2-8mmØ
Shear Reinf:-	NIL
Opening Diameter (mm):-	63.00mm
Opening dist from edge (mm):-	350mm
Failure Load (KN):-	76.00KN (2xP)
Zone of Failure:-	FLEXURE



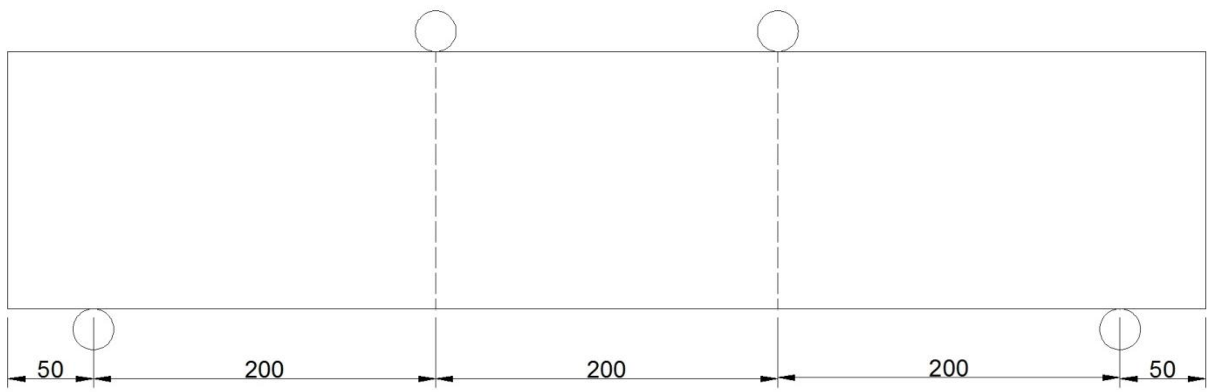


R.C.C Beam No:-	8
Concrete Strength:-	29.20N/mm^2
Tension Reinf:-	2-10mmØ
Top Reinf:-	2-10mmØ
Shear Reinf:-	NIL
Opening Diameter (mm):-	63.00mm
Opening dist from edge (mm):-	350mm
Failure Load (KN):-	85.00KN (2xP)
Zone of Failure:-	FLEXURE





R.C.C Beam No:-	9
Concrete Strength:-	29.20N/mm^2
Tension Reinf:-	2-10mmØ
Top Reinf:-	2-12mmØ
Shear Reinf:-	NIL
Opening Diameter (mm):-	63.00mm
Opening dist from edge (mm):-	350mm
Failure Load (KN):-	87.00KN (2xP)
Zone of Failure:-	FLEXURE



R.C.C Beam No:- 10

Concrete Strength:- 33.92/mm^2

Tension Reinf:- 2-8mmØ

Top Reinf:- 2-8mmØ

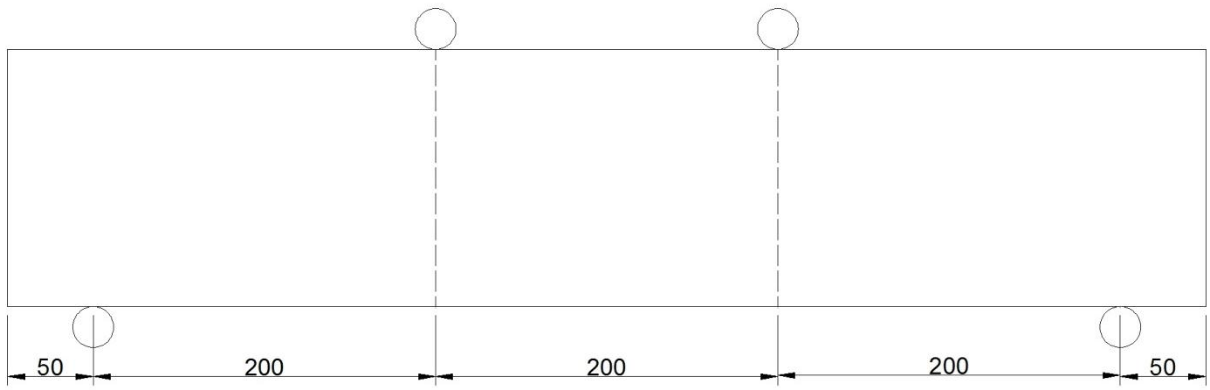
Shear Reinf:- 2-lgd, 8mmØ@100mmc/c

Opening Diameter (mm):- 63.00mm

Opening dist from edge (mm):- 190mm

Failure Load (KN):- 74.50KN (2xP)

Zone of Failure:- SHEAR




2/6/11


2/6/11

R.C.C Beam No:- 11

Concrete Strength:- 33.92/mm^2

Tension Reinf:- 2-8mmØ

Top Reinf:- 2-8mmØ

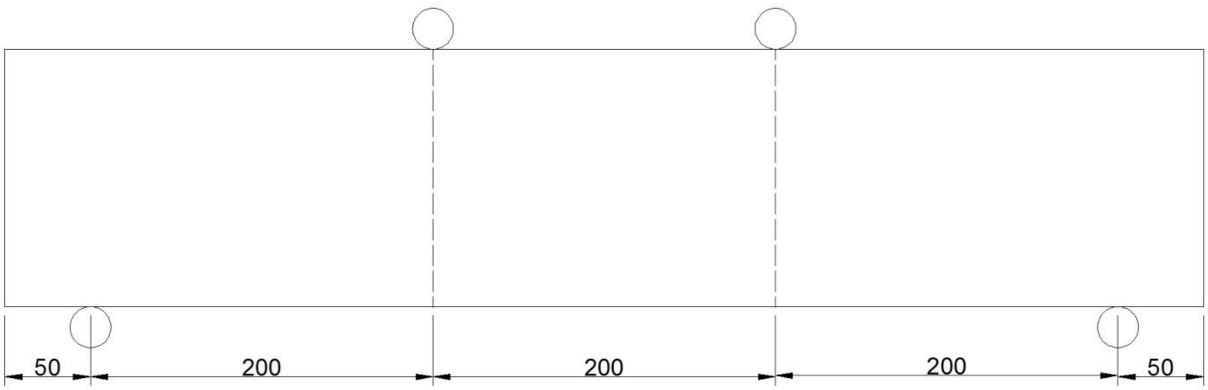
Shear Reinf:- 2-lgd, 8mmØ@75mmc/c

Opening Diameter (mm):- 63.00mm

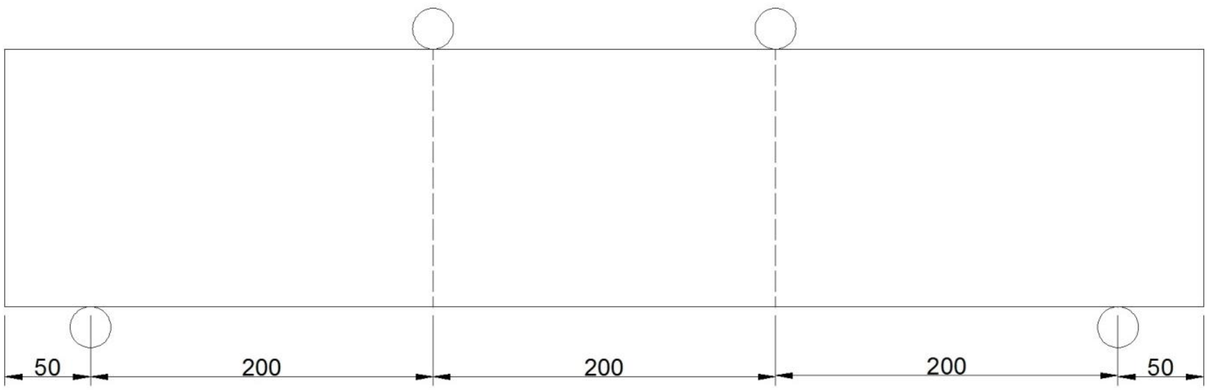
Opening dist from edge (mm):- 190mm

Failure Load (KN):- 85.00 (2xP)

Zone of Failure:- FLEXURE



R.C.C Beam No:-	12
Concrete Strength:-	33.92/mm^2
Tension Reinf:-	2-8mmØ
Top Reinf:-	2-8mmØ
Shear Reinf:-	2-lgd, 8mmØ@50mmc/c
Opening Diameter (mm):-	63.00mm
Opening dist from edge (mm):-	190mm
Failure Load (KN):-	86.00 (2xP)
Zone of Failure:-	FLEXURE



CHAPTER 9

F.E.M Modeling

9.1. F.E.M Model Properties:-

Using the data from the test conducted F.E.M models was made for plain concrete beams on the STAAD-Pro software. The models made were having the following properties:-

a. Element Size:- 7mm x 7.5 mm x 7.5mm (cuboid)

b. No of elements:- 40000(approx.) for beams without openings

c. Opening Sizes:- 0mm,40mm,50mm,64mm,75mm(dia)

d. Support Conditions:- Simply supported

9.2. Material Properties:-

The material properties were taken ass following:-

a. E_s = 2.62969 x10^7 KN/m^2

b. Poissons Ratio= 0.19

c. Density of Concrete= 22.75KN/m^3

d. Shear Modulus, G= 1.10365 x 10^7 KN/m^2

9.3. Charts and relations from analysis of the models:-

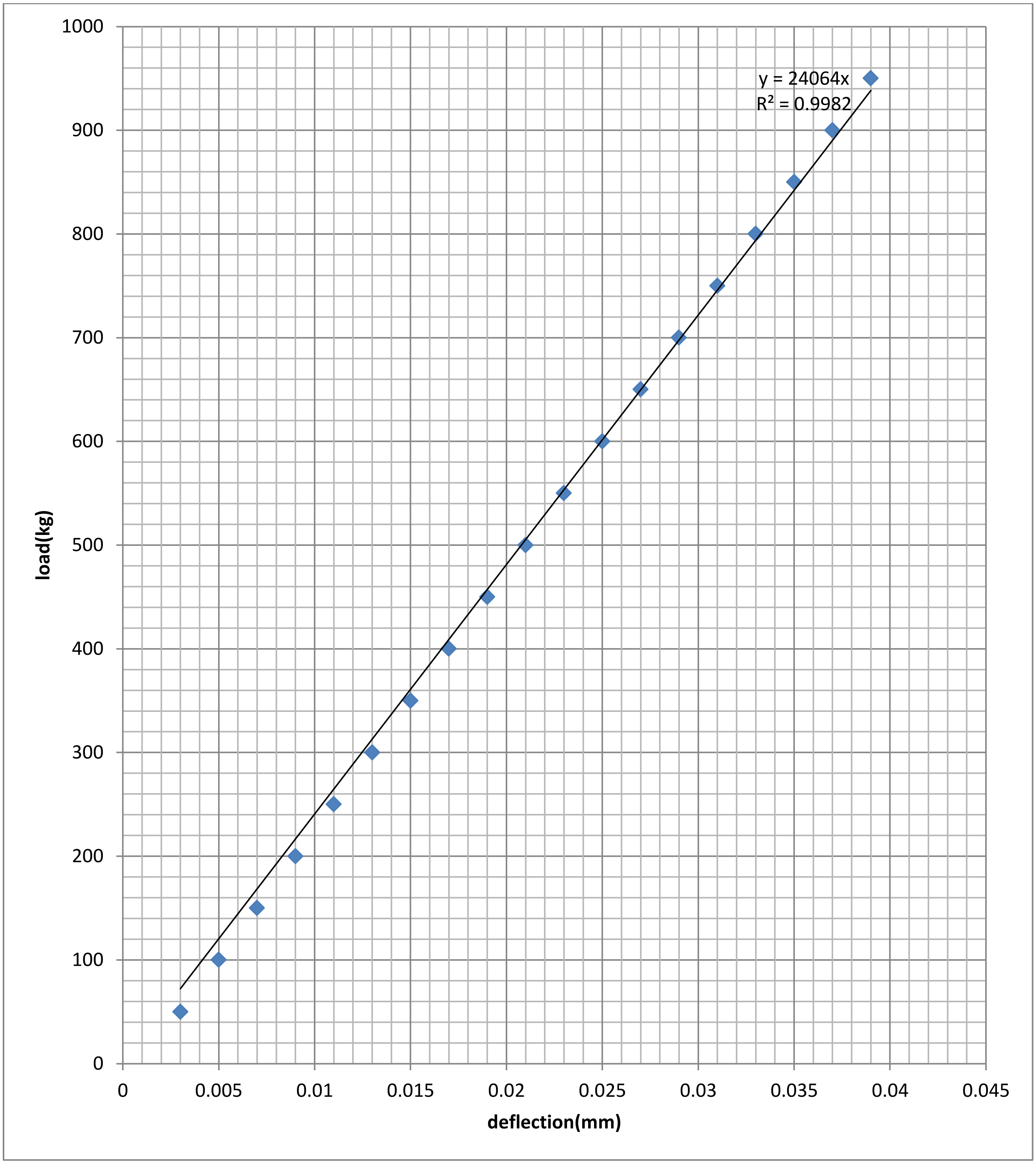


Chart.9.1.Load Vs Deflection for Standard Beam (no opening)

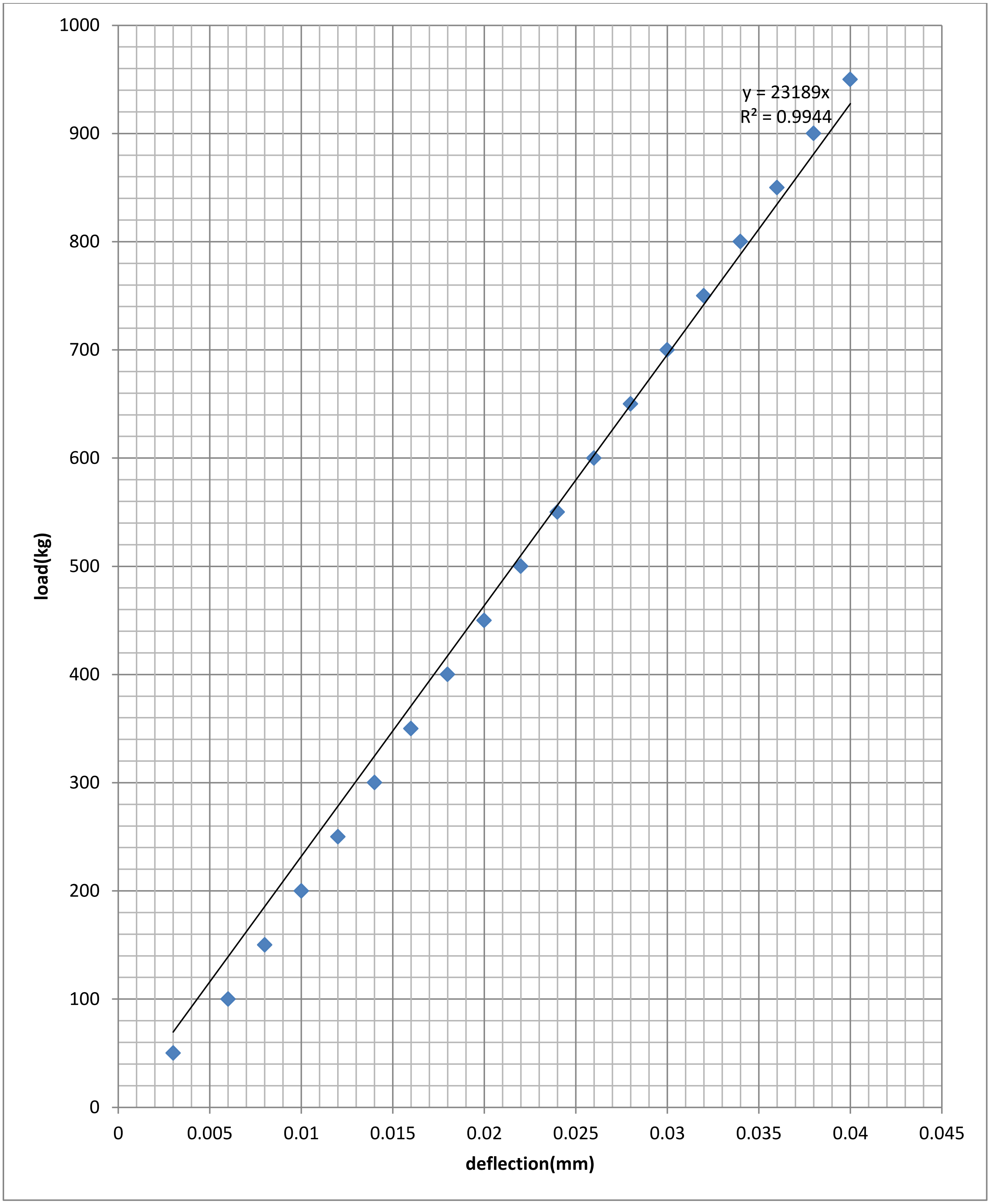


Chart.9.2.Load Vs Deflection for Beam with 40mm Opening

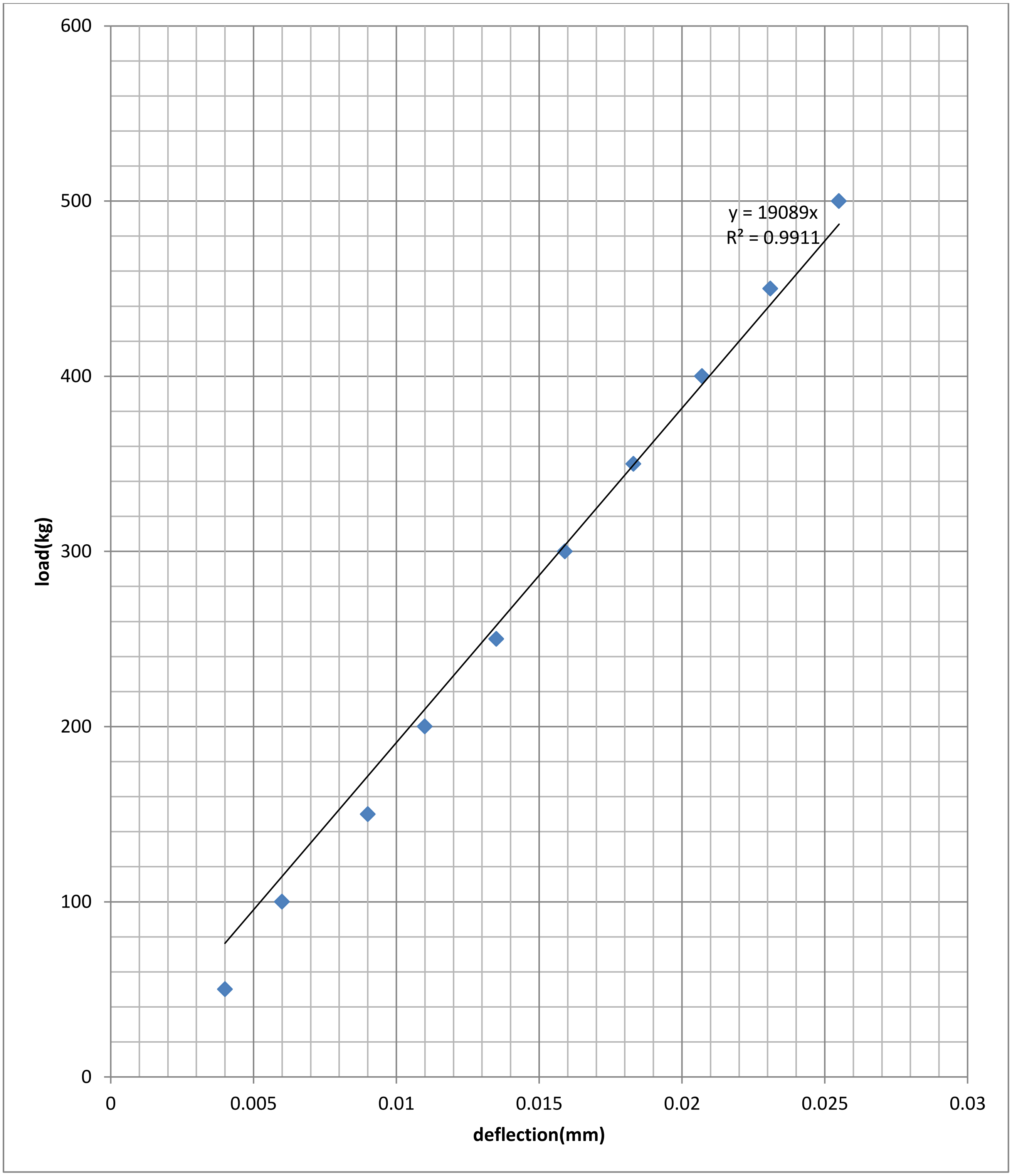


Chart.9.3.Load Vs Deflection for Beam with 64mm Opening

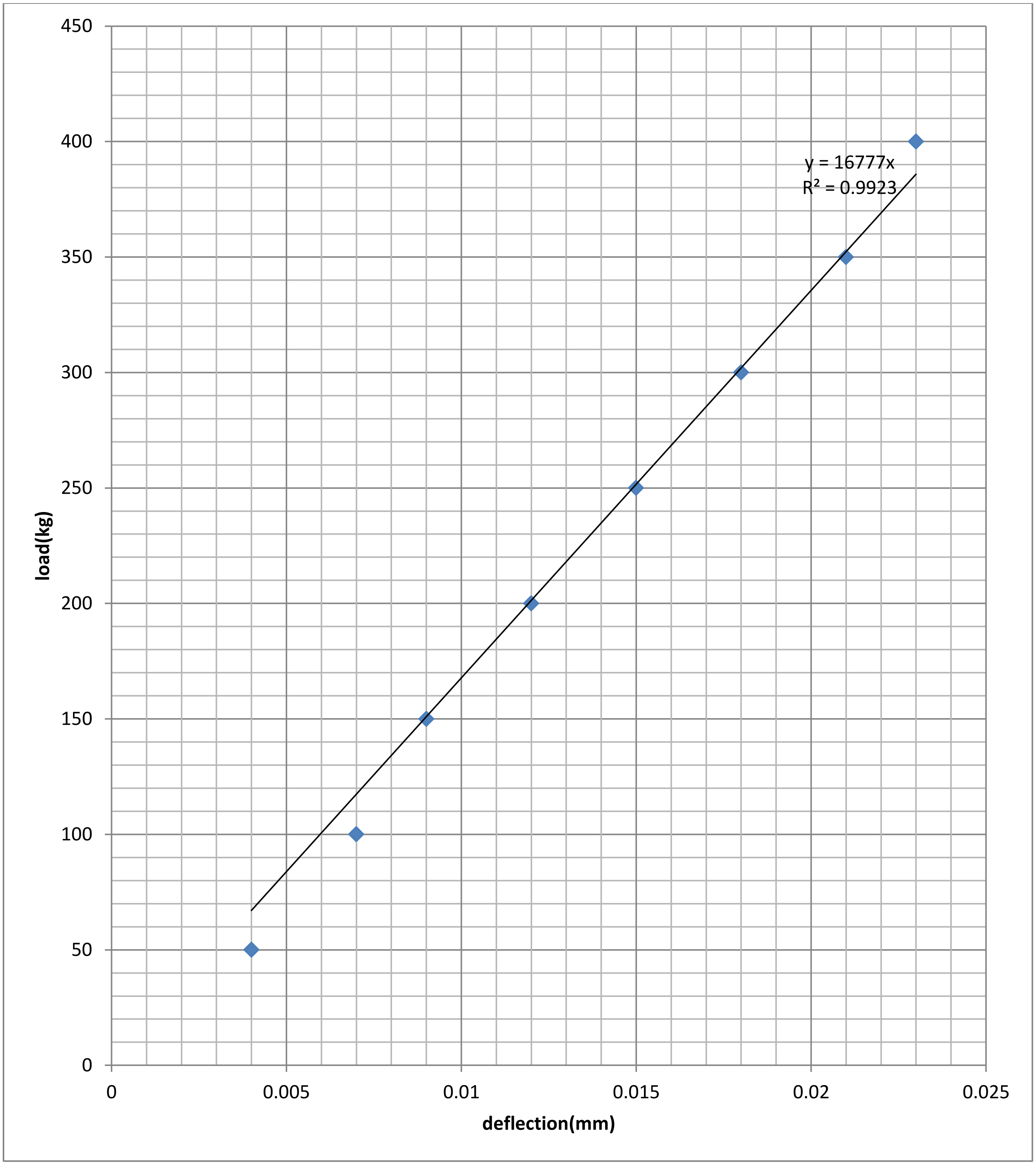


Chart9.5.Load Vs. Deflection for Beam with 75mm Opening

9.4. Stress in Beams (75mm opening) from F.E.M Model:-

1. At 50kg load at each point of load:-

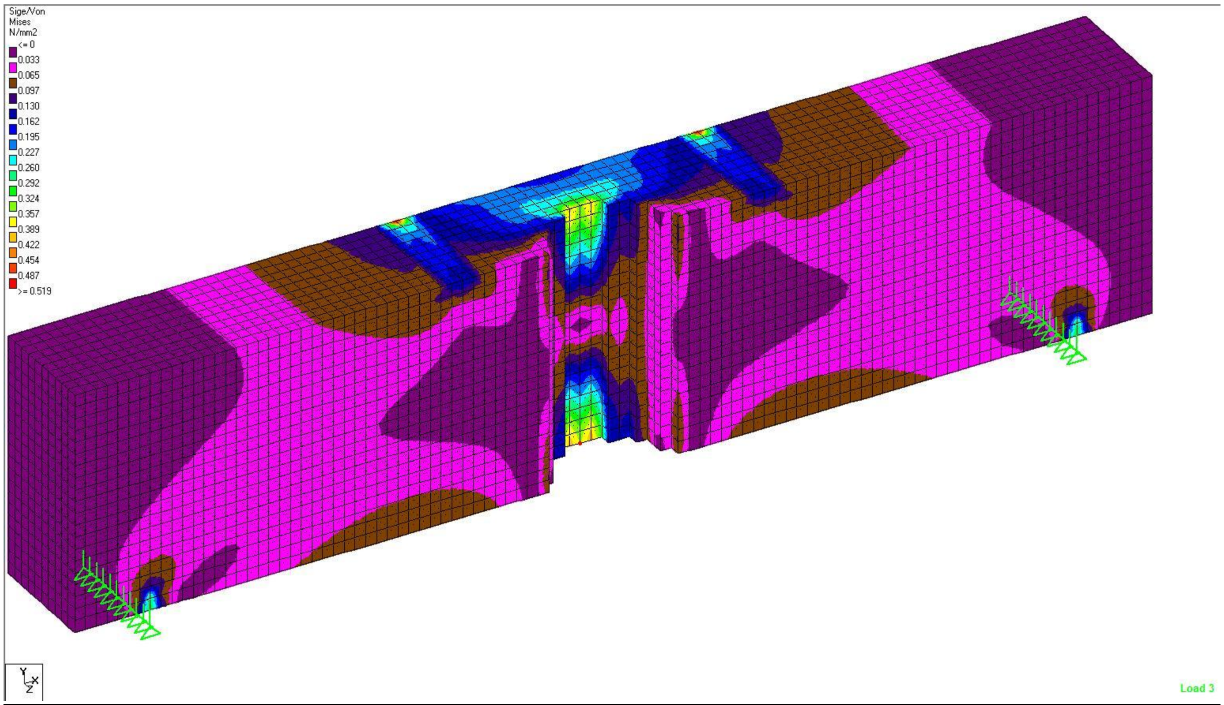


Fig.9.1.

2. At 75kg load at each point of load:-

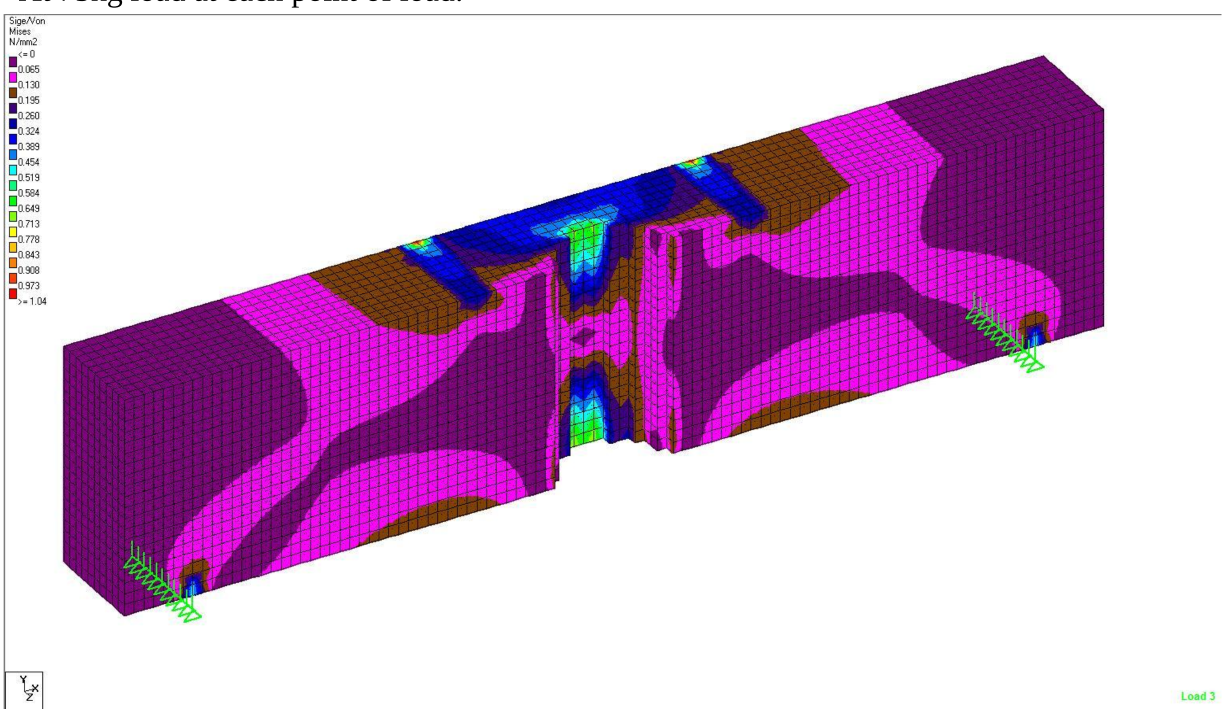


Fig.9.2.

3. At 200kg load at each point of load:-

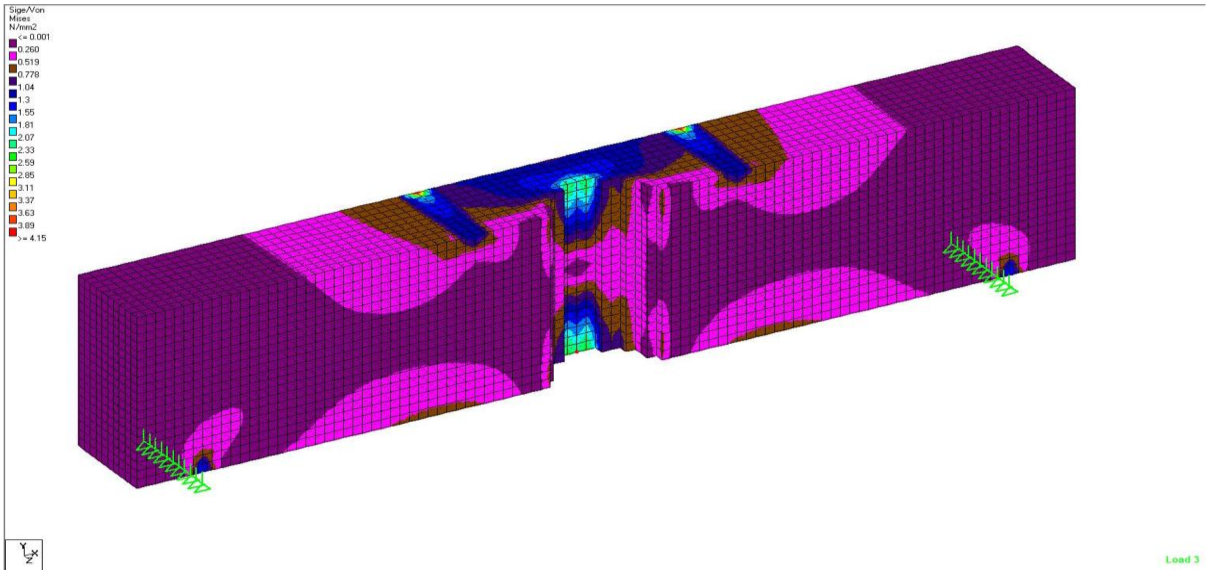


Fig.9.3.

4. At 300kg load at each point of load:-

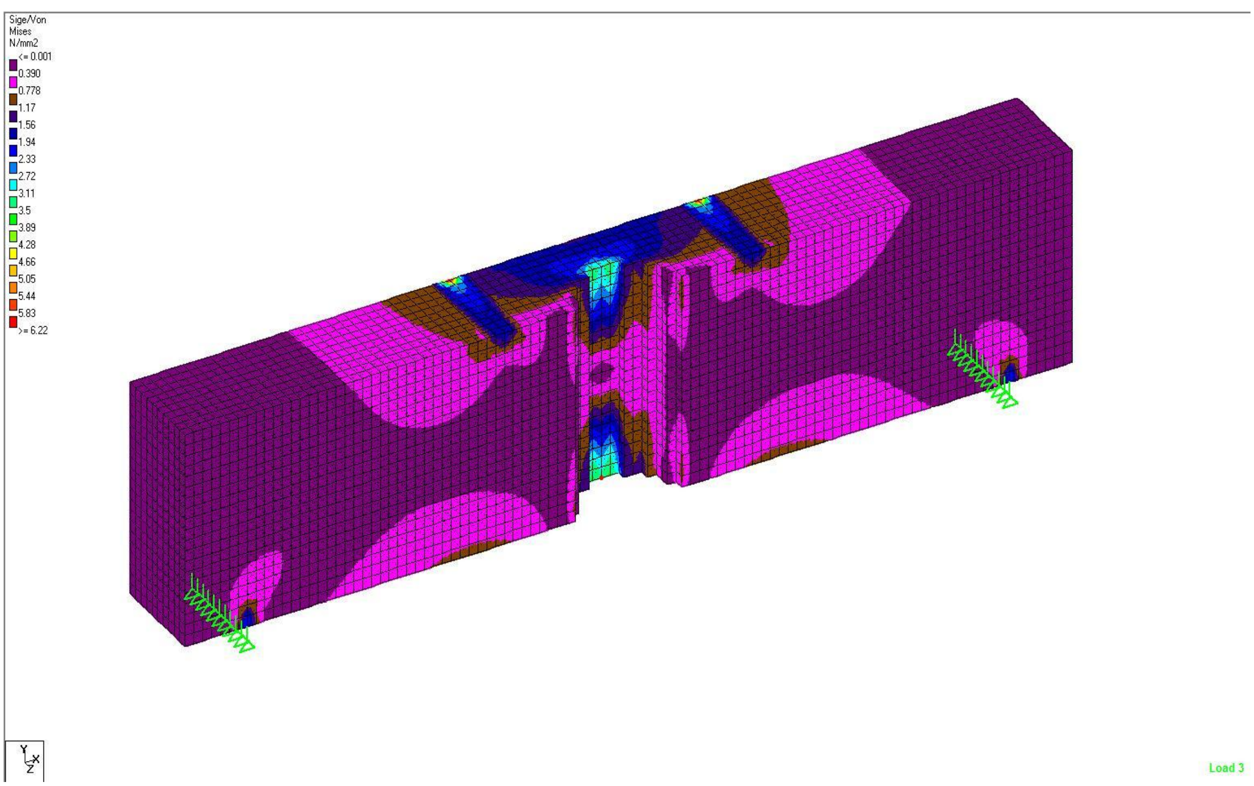


Fig.9.4.

5. Deflected shape of FEM beam model under Loading:-

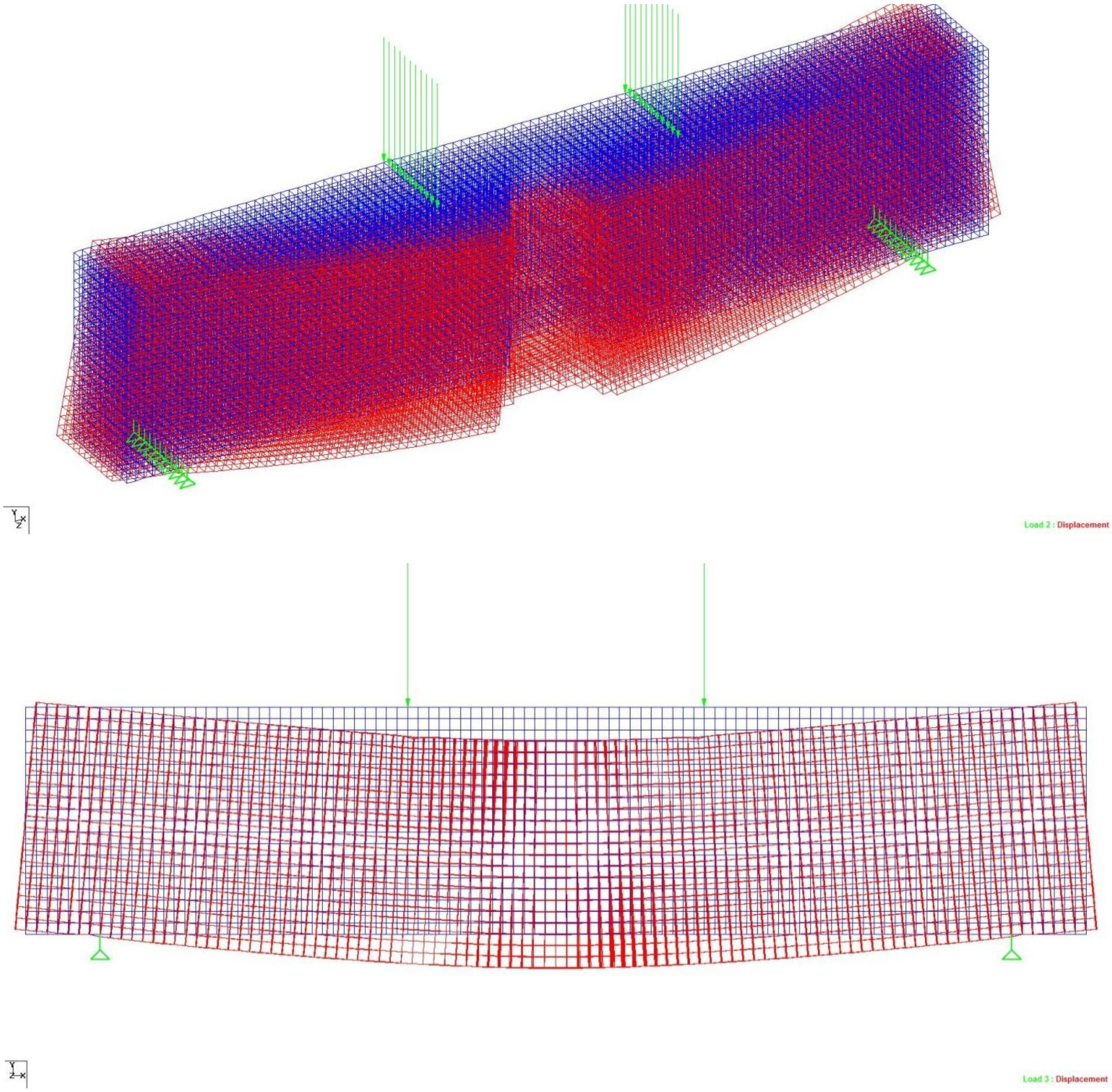


Fig.9.5.

CHAPTER 10

Discussion & Conclusion

10.1. General discussion

The tests conducted shows a good amount of consistency, and correlate with each other in a wide variety of ways, and the data procured from these tests can be used for the further study of this topic & can be extended for the study of R.C.C beams with openings.

The Load deflection data from the experimental setup & the FEM model are not very consistent with each other even though both of them show an almost perfect linear relationship. To correct the discrepancies, in the above stated test, the material constants should be found out with greater accuracy. The nonlinear behavior of concrete should also be given due importance, and should be accounted for the models to be prepared.

10.4 Strength Calculation of R.C.C Beam:-

DESIGN THEORY:-

Considering a Parabolic stress distribution in the compression zone of the beam

Total Compressive force from the parabolic stress block is calculated with the following assumption:-

- The top most fiber in compressive zone attains the maximum compressive strength of concrete (f_{ck}) at the point of the failure of beam.
- The failure strain in concrete is taken to be .0035.
- Therefore, the characteristic curve of concrete is take as shown below,

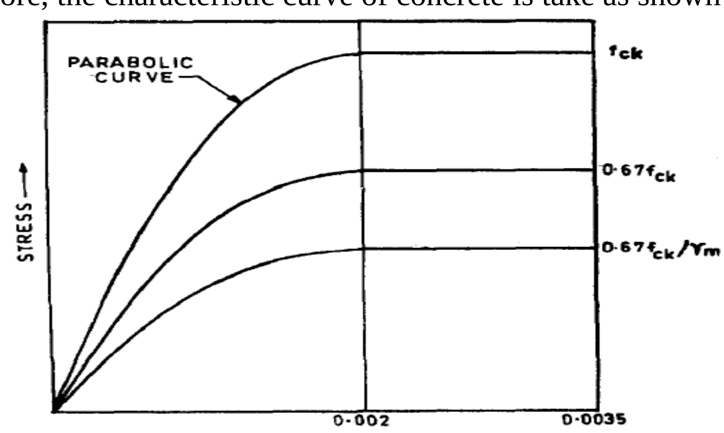


Fig10.1. Stress –Strain Curve for concrete; IS:456-2000

- Total resultant compressive force,

C = Area of (Rectangular stress block – Area of Outer Parabola)

$= (f_{ck} . x .b) - \{f_{ck} . (\frac{0.57}{3}) . x . b\}$

$= \mathbf{0.81 . f_{ck} . x . b}$

- Location of resultant with respect to the top fiber, K:-

  Taking moments of the resultant forces of rectangular, parabolic stress block and the total resultant force, about the Neutral axis and equating, taking the distance of the resultant form the top most fiber to be, K.

  Therefore we have,

$$(0.81 . f_{ck} . x . b) . (x - b) = (f_{ck} . x . b . \frac{x}{2}) - [f_{ck} .\frac{(0.57 . x)^2}{12}. b]$$

K = 0.409 . x

From the above we have the following modified stress block as shown:-

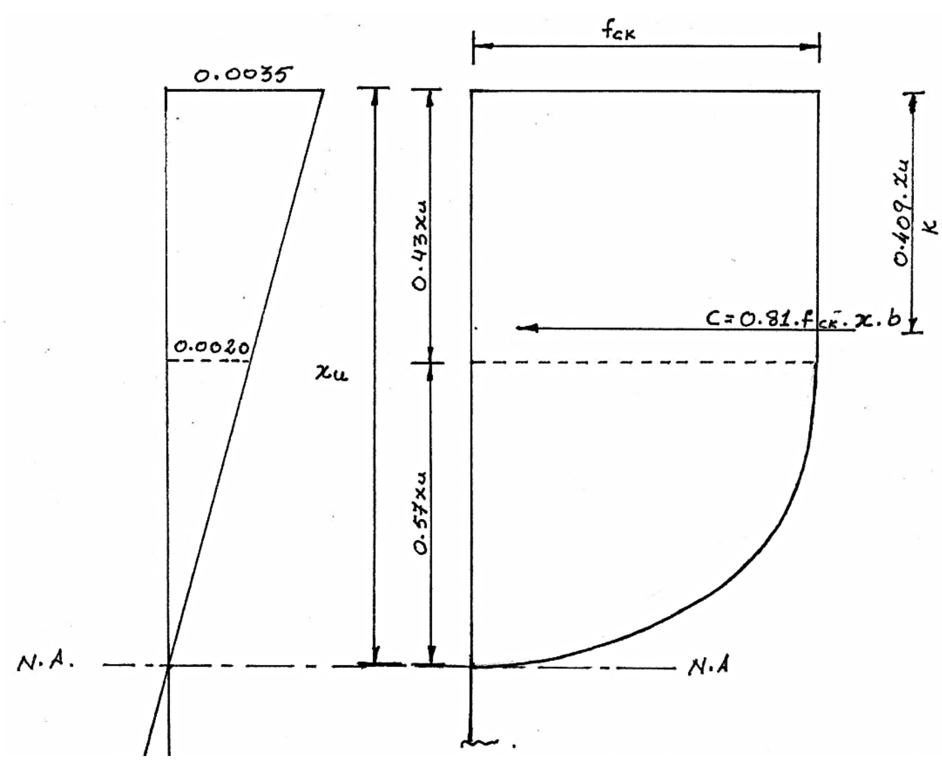


Fig10.2. Modified Stress Block

- Hence we have, from the new stress block:-

$$\frac{Xumax}{d} = .04375, \quad \text{for Fe500}$$

From the use of the above calculations, the ultimate strength of the beams were predicted, as mentioned in table-8.1, and it was seen to be in good

10.3. Data analysis

We can see from the Table 6.1, of this report that the provision of opening in a beam does weaken the beam. There is a considerable reduction in the strength of the beam as shown. The failure of the beam also occurs in the vicinity of the opening, this is due to the stress concentration at the opening, which is verified by the FEM stress analysis.

From the chart-10.1 we can see that, the slope Load-deflection curve of beams with openings plotted against the diameter of the beam opening, it shows that as the opening increases the slope decreases, it has a quadratic relation to each other. Similarly FEM model data, Chart-8.2 also shows a similar behavior.

Chart-10.4, shows that the increase in the diameter of the opening has a considerable impact on the strength of the beam (Opening in Flexural Span), the reduction in strength has a almost quadratic relation to the opening dia provided. In the chart-10.5, the effect of variation of the opening in the shear span can be seen, it is more of a linear reduction in strength

From the chart-10.3 for R.C.C beam with 63mm opening, we can infer that the increase in area of steel area of steel, reduces the deflection considerably caused due to the opening provided.

From the Table-8.1, we can see that in R.C.C Beams, the opening (63mm) when provided in the flexural span of the beam, with no shear reinforcement, the failure occurs in the vicinity of the opening (In the flexural span), but for the similar beam without opening the failure is due to shear and at failure occurs at much higher load . This shows that the considerable weakening of the beam due to large openings.

When beam with opening is provided with compression reinforcement, there is an improvement in the performance of the beam, which can be seen in chart-10.6. it also shows the reduction in the effectiveness as the compression steel increases. The compression reinforcement hence plays a very important role when the opening is in the flexural span, as in this span concrete takes almost all the compressive stresses, the reduction of the concrete area causes higher stresses and in turn causes premature failure of the beam.

In an R.C.C beam, when the opening is provided in the shear span, the role of the, shear reinforcement increases considerably, as we can see from table-8.1 that as we increase the shear reinforcement there is an increase in the load carrying capacity of the beam. And also the failure is due to failure in the flexural zone rather than the shear span, as in the case of the lower shear reinforcement.

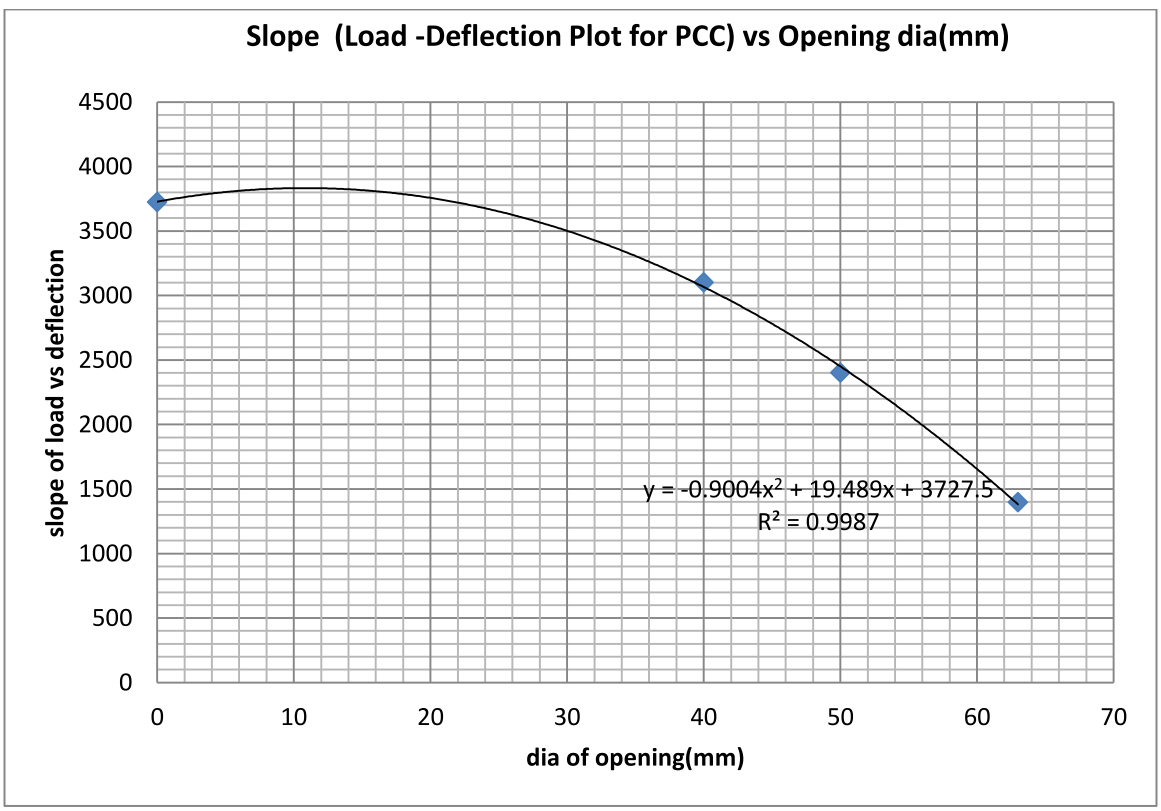


Chart-10.1. Slope(Load Vs deflection plot) vs Opening dia

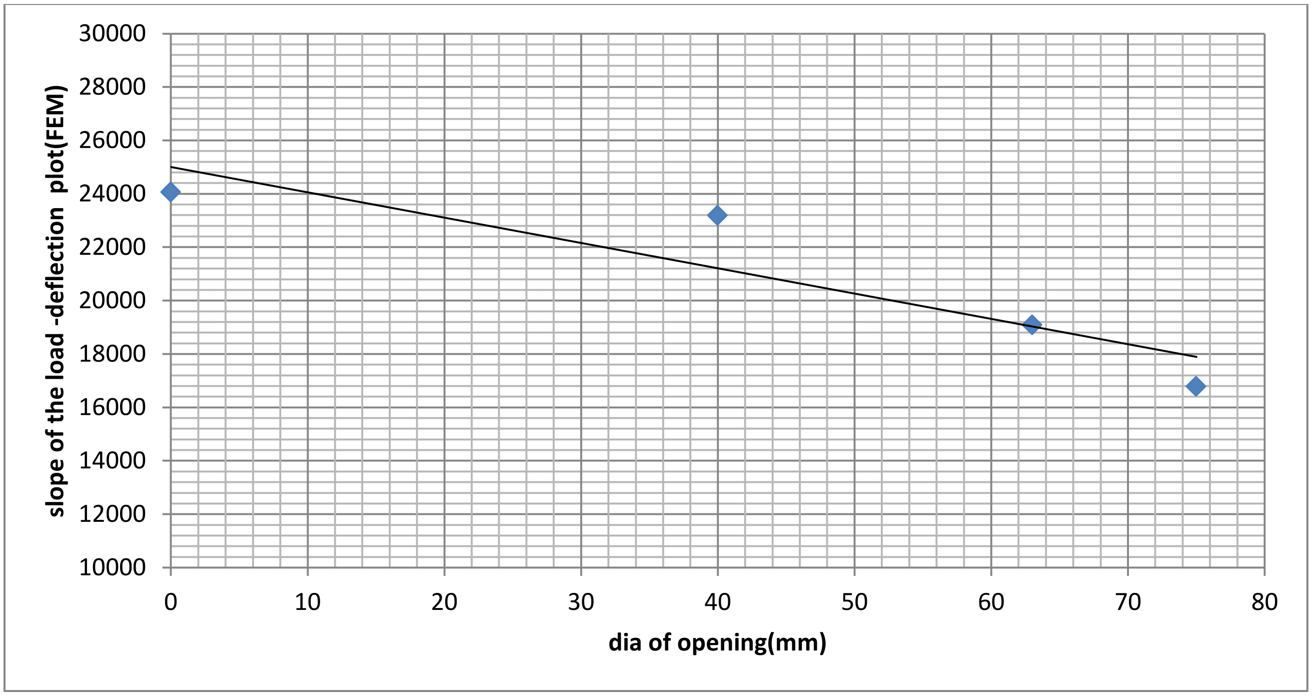


Chart-10.2. FEM-Slope(Load Vs deflection Plot) vs. Dia of opening

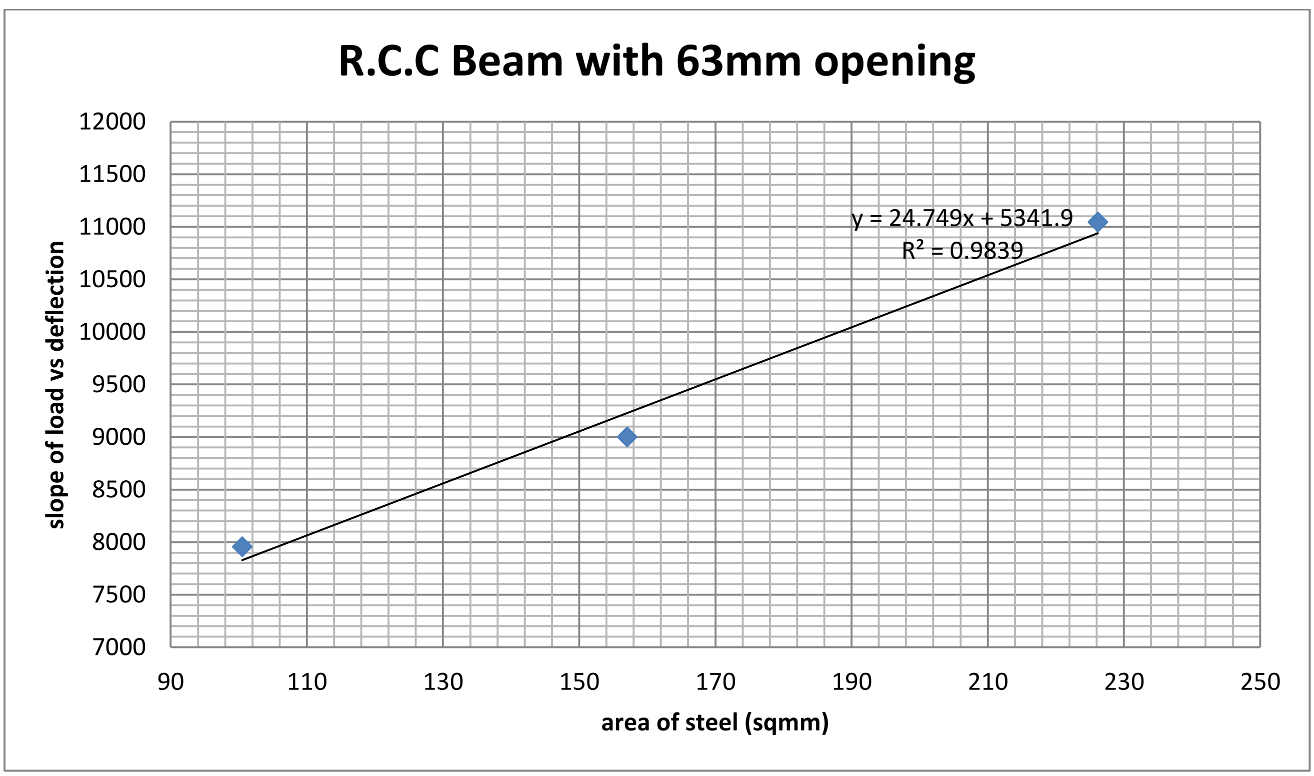


Chart-10.3. Slope (load vs deflection plot) Vs Area of tension steel

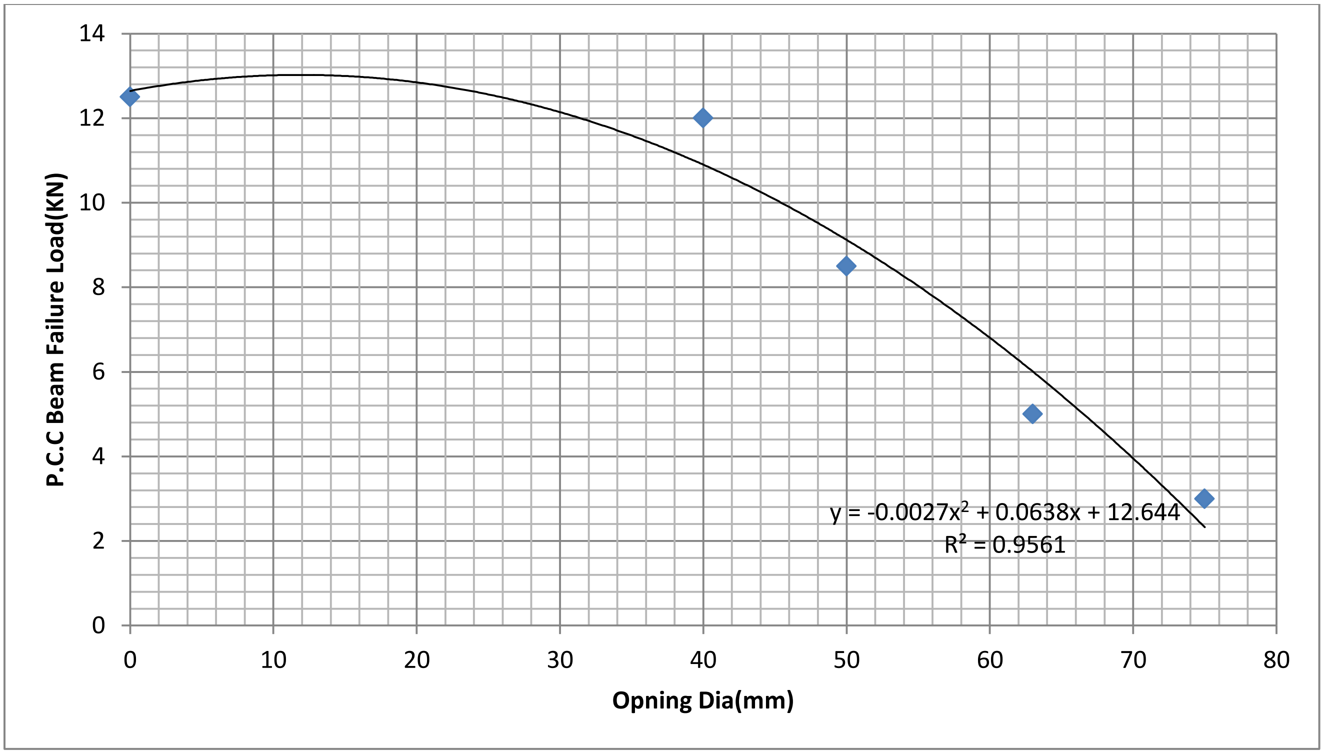


Chart-10.4. P.C.C Beam- Failure Load Vs Opening Dia (Flexural Span)

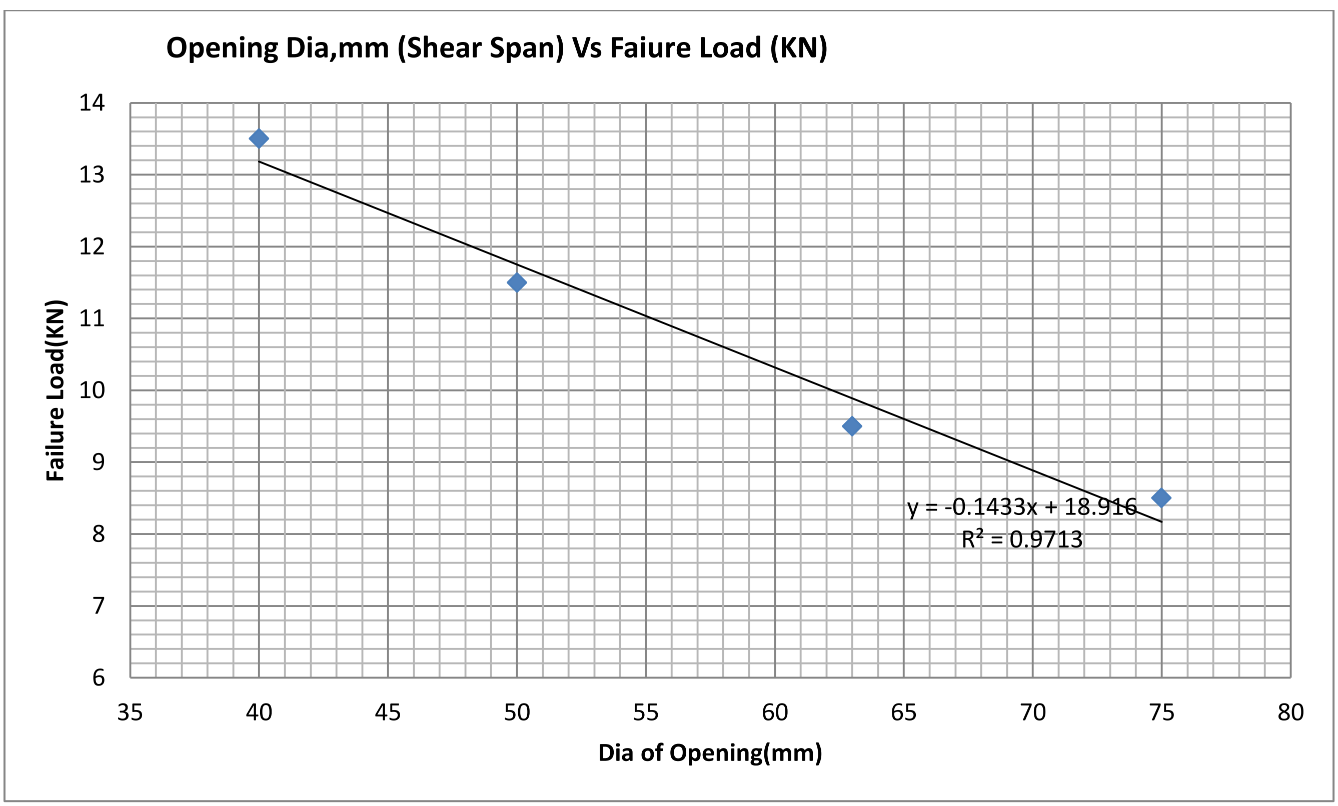


Chart-10.5. P.C.C Beam- Failure Load Vs Opening Dia (Shear Span)

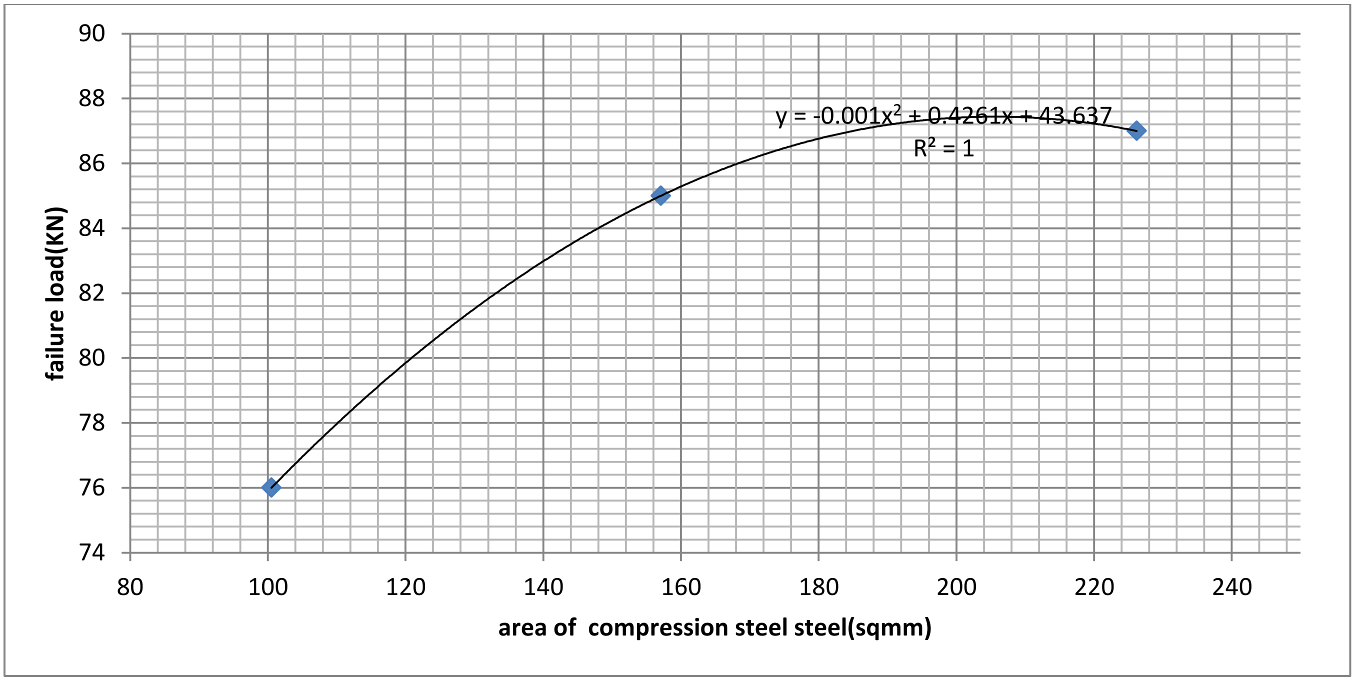


Chart-10.6. Failure Load Vs Area of Compression Steel(63mm opening, centre span)

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