4 EXPERIMENTAL WORK

An experimental work was carried out to study the size effect behavior of Deep Beams under Three-point and Four-point bending test. TMT (Thermo Mechanically Treated) bars used as longitudinal reinforcement steel. The main aim of this experimental work to establish the size effect parameter in previous researcher's formula and code equation. Deflection patterns compare cracking characteristics like cracking load, cracking pattern, crack width and modes of failure for RCC Moderate Deep beam and Fibrous Moderate Deep Beam without web reinforcement across its width. Influence of different size effect parameters were examined on specimens. These parameters were the Shear span to Depth ratio (a/d), The Longitudinal main reinforcement ratio (ρ), Effective depth (d),Ratio of effective depth to maximum size of aggregate (d/d$_a$), Effective length to overall depth ratio (L$_e$/D), Compressive strength of concrete (fck).

Details of the geometry and Reinforcement configurations, the Materials properties and the test set up for each specimen explain here.

4.1 DETAILS OF TEST SPECIMENS

A total 75 specimens were casted and tested under three-point load and Four Point load bending test. Beam sizes selected as Prof. BAZANT'S size effect laws, which are given as under.

Minimum Width(b) and depth (d) > 3 x da.(da = size of aggregate)

Provided Width(b) = 75 mm >(3 x da = 3 x 20 = 60mm),

Provided Depth(D) = 150 mm >(3 x da = 3 x 20 = 60mm)

Largest Depth(D) >10 x da,

Provided Largest Depth (D) = 600 mm> (10xda= 10 x 20 = 200mm)

The ratio $\frac{\text{Largest Depth}}{\text{Smallest Depth}}$ = 4   Provided Ratio = $\frac{600}{150}$ =4

d/da = 4,8,16 acceptable and d/da = 3,6,12,24 preferable. All specimen should be Geometrical similar in two directions (span and Depth) with third dimension kept constant (width). Span = Varying, Depth = Varying and Width = Constant. Width of all the beams (b) were kept constant as 75mm. In this study Le/d and a/d ratio remain same for all specimens.

Test No.1

Total 21 Moderate Deep Beam specimens tested under Three-point load and Four-point load. Three types of beams were considered namely i.e. Plain concrete, RCC and SFRC beam having Le/D= 2. Each series have 7 beams depth ranging from 150 mm to 600 mm and span 300 mm to 1200 mm. Size of all beams and reinforcement details is given below.

Table 4.1 Details of Moderate Deep Beams with Reinforcement

Width (mm)	Depth (mm)	Overall Span (mm)	Ast Req (mm^2)	Dia Of Bar (mm)	No. Of Bar	Ast Prov. (mm^2)	Develop. Length (mm)
75	150	400	33.75	8	1	50.24	257.9
75	225	550	50.63	10	1	78.50	322.4
75	300	700	67.50	10	1	78.50	322.4
75	375	850	84.38	8	2	100.48	257.9
75	450	1000	101.25	12	1	113.04	386.8
75	525	1150	118.13	10	2	157.00	322.4
75	600	1300	135.00	10	2	157.00	322.4

Test No. 2

The Test specimens consists of 24 nos. Moderate Deep Beam having Effective span to Overall depth ratio 3 (i.e Le/D =3). The test specimen consists of 2 series Fibrous RCC (10 number) and Fibrous Layered RCC (14 number). Beams have depth ranging from 100 mm to 400 mm and Effective span ranging from 300 mm to 1200 mm.

Descriptions of all beams with amount of Reinforcement are given as follow

Table 4-2 Details of Moderate Deep Beams with Amount of Reinforcement

| Width (mm) | Depth (mm) | Overall Span (mm) | Main Reinforcement | | | Layered Reinforcement | | | |
			Dia. Of Bar (mm)	No. Of Bar	Ast Prov. (mm^2)	No. Of Layer	Dia. Of Bar	No.OfBarInEach Layer	Ast Prov. (mm^2)
75	100	400	8	1	50.24	-	-	-	-
75	150	550	8	1	50.24	-	-	-	-
75	200	700	8	1	50.24	1	8	1	50.24
75	250	850	8	2	100.48	1	8	1	50.24
75	300	1000	8	2	100.48	1	8	1	50.24
75	350	1150	10	2	157	2	8	1	100.48
75	400	1300	10	2	157	2	8	1	100.48

Description of all beams with amount of reinforcement

NOTE: Main Reinforcement is provided in both series of beams, while Layered reinforcement is provided only in Fibrous Layered RCC series of beam.

Test No. 3

Total 30 nos. of Moderate Deep Beams which were divided in three series RCC(10number), PFRC(10number) and SFRC (10number).

All 10 beams span ranging from 700mm to 1500mm. Effective depth ranging from 150mm to 400mm.The development length at the end of the beam used to anchor the main longitudinal reinforcement was calculated as per IS: 456-2000.

Table 4- 3 Description of all beams with Amount of Reinforcement

| a/d Ratio	Type of Beam	Width of Beam (b) mm	Effective Depth of Beam (d) mm	Overall Depth (D) mm	Shear Span (a) mm	Effective Span (le) mm	Overall Span (l) mm	No.of Bar	Dia of Bar
1	A2	75	200	225	200	1000	1100	2	8
	B	75	250	275	250	1100	1200	2	10
	C	75	300	325	300	1200	1300	2	10
	D	75	350	375	350	1300	1400	2	10
	E	75	400	425	400	1400	1500	2	12
2	F	75	150	175	300	600	700	2	8
	A1	75	200	225	400	800	900	2	8
	H	75	250	275	500	1000	1100	2	10
	I	75	300	325	600	1200	1300	2	10
	J	75	350	375	700	1400	1500	2	10
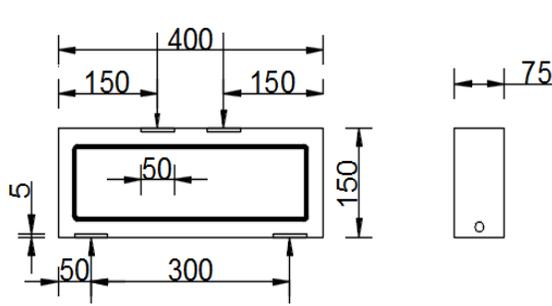
Beam Size: 400 X 150 X 75
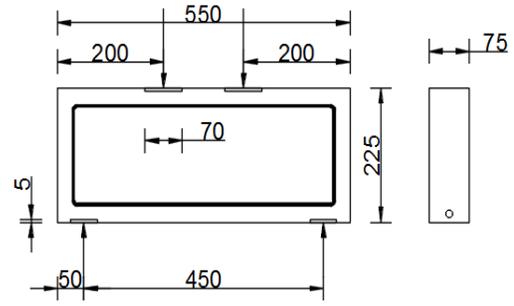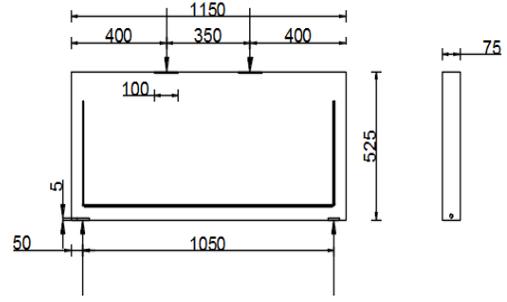
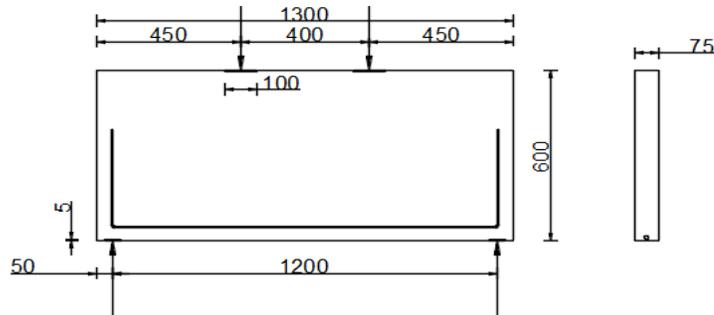Beam Size: 550 X 225 X 75
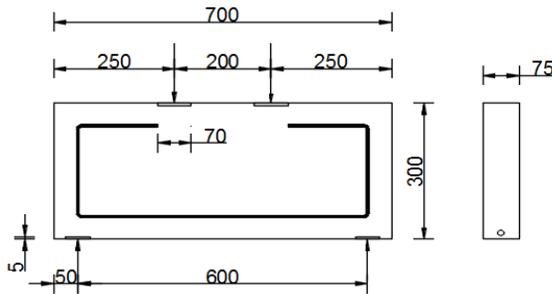
Beam Size: 700 X 300 X 75
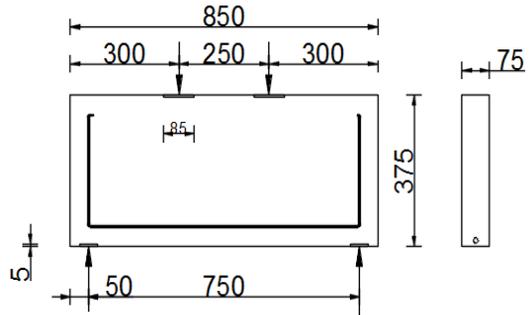
Beam Size: 850 X 375 X 75
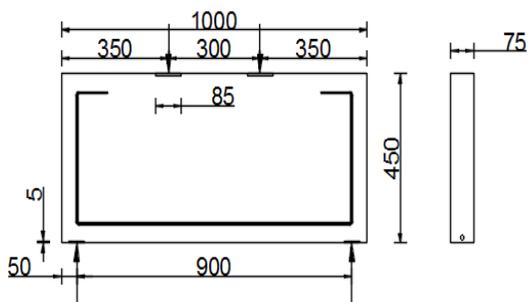
Beam Size: 1000 X 450 X 75

Beam Size: 1150 X 525 X 75

Beam Size :1300 X 600 X 75

Figure. 4-1 Details of Beam Size
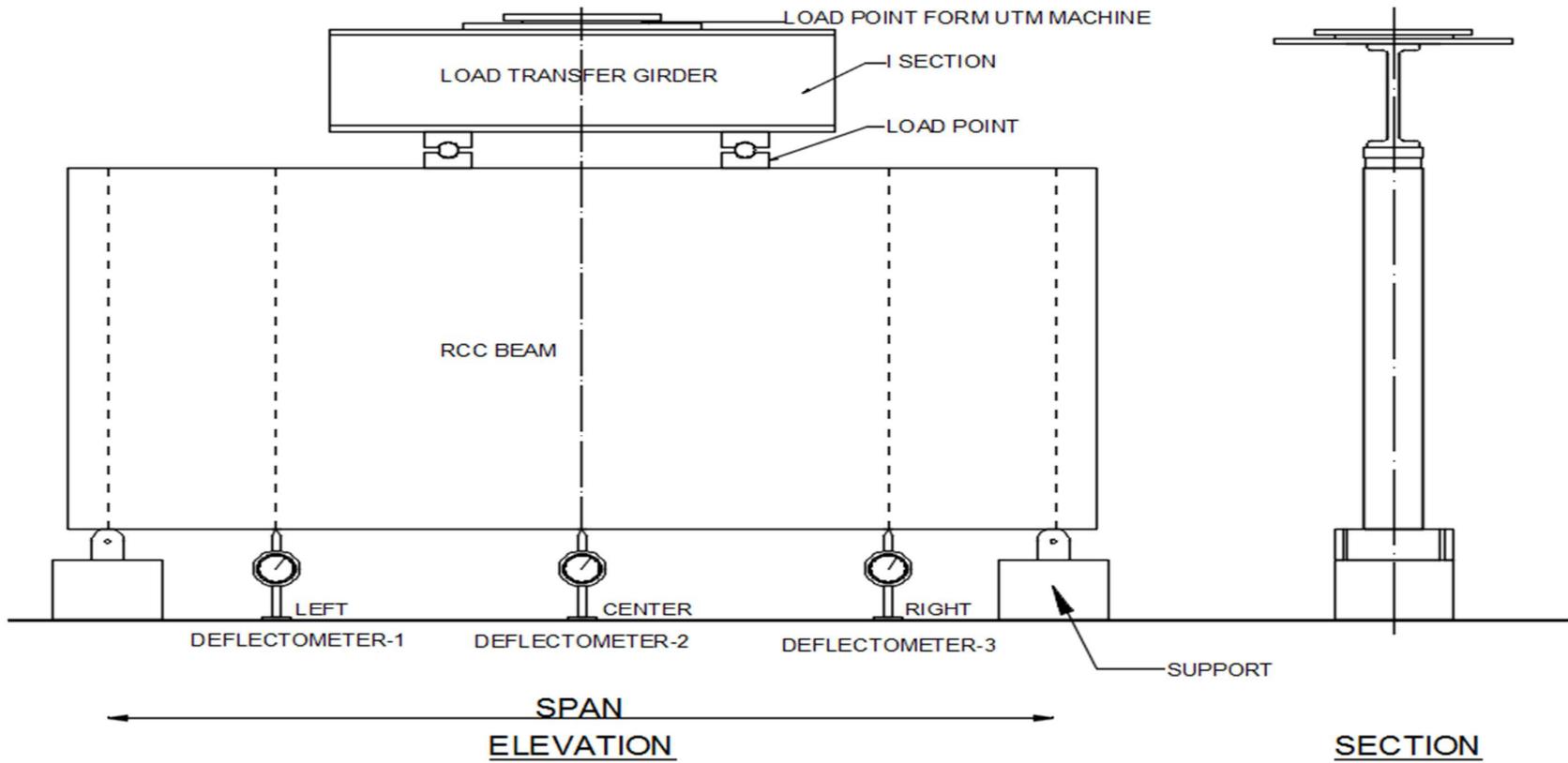
Figure. 4-2 Load Test Arrangement for Two Point Loading

Figure.4-3 Different types of Beams photographs.

Two types of bearing plates used for supporting and loading point in Moderate Deep Beam. The size of bearing plate is 100 mm length x 75 mm width x 6 mm thick and 75 mm length x 75 mm width x 6 mm thick. Concrete cover 25 mm at bottom and side of the beam. In addition to these beams,

standard size of cubes and cylinders were casted to evaluate the compressive strength and split cylinder test for each group.

4.2   BEAM NOTATION

Beams were classified according to its series with respect to depth and span. First letter indicates series as P for Plain R for Reinforced and F for Fiber reinforced and suffix latter indicates overall depth in mm. second letter indicates effective span of specimen.

A2/RC	A2 indicate Beam serial number	RC indicate types of beam i.e. RCC /PFRC / SFRC
R150	R indicate the series	150 indicate Depth in mm
S300	S indicate Effective span	300 is span
RL 25	RL indicate Beam series	25 indicate the Depth in cm

4.3   MATERIALS

4.3.1 Cement

Specimens were casted using O.P.C 53 grade of cement. It was stored in a dry place throughout its usage. Specific gravity of the cement was 3.15. Total 30 bags of cement were required to cast all the specimens, cubes, cylinders.

Figure 4-4 Cement, Sand and Coarse Aggregate

4.3.2 Coarse and Fine Aggregates

Dry and clean river sand was used to prepare the concrete mix. Sand was sieved through 4.75mm I.S sieve and all the silt and organic impurities were removed prior to prepare concrete. Specific gravity of sand was 2.7. We have used fine aggregates of zone-II as per IS: 456-2000. Basalt gravel of size 20mm was used for concrete mix. Blending ratio of coarse aggregate to fine aggregate is found out and taken as 65:35. All the dust particles were removed by soaking in water and allow saturated surface dry condition before mixing.

4.3.3 Water

Clean potable water was used for mixing of concrete and for curing of all the beam specimens.

4.3.4 Reinforcement

The reinforcing steel used in this project consisted of grade 500. High strength deformed steel bars conforming to IS 1786 of 8mm, 10mm and 12mm diameter were used as longitudinal tension reinforcement.

Figure -4-5 Reinforcement Cutting and Bending Machine

Table 4-4 Details of Tensile Reinforcement

| BEAM | Tension steel Reinforcement | | Grade |
	No of bars	Bar diameter(ϕ) mm	
A2	2	8	HYSD500
B	2	10	HYSD500
C	2	10	HYSD500
D	2	10	HYSD500
E	2	12	HYSD500
F	2	8	HYSD500
A1	2	8	HYSD500
H	2	10	HYSD500
I	2	10	HYSD500
J	2	10	HYSD500

Figure   4- 6 Photograph of Reinforcement

4.3.5 Properties of Fibers

Table 4-5 properties of Carbon steel fibres

No.	Property	Test 1	Test 2 & 3
1	Cross Section	Circular	Circular
2	Length	38 mm	30 mm
3	Equivalent diameter	0.45 mm	0.6 mm
4	Aspect ratio	80	50
5	form	Circular Corrugated	Hook end type
6	Volume	1 % by volume of concrete	0.7 % by volume of concrete
7	Density	7850 kg/m^3	7850 kg/m^3

Table 4-6 Properties of Polypropylene Fibres

No.	Property	Type
1	Cross section	circular
2	Length	6 mm
3	Equivalent diameter	30×10^{-3} mm
4	Aspect ratio	200
5	Form	Monofilament
6	Volume	0.7 % by volume of concrete
7	Density	910 kg/m^3

Figure 4-7 Steel & Polypropylene fibers

.

4.3.6 Concrete Mix

Figure 4-8 Photograph of Concrete Mix with Fibers

4.3.7 Formwork

Different mould of steel channel section, angle section and sheet were fabricated to accommodate in different sizes of beams. Thickness of sheet used was about 3mm while width of web was kept 75mm of channel section. Every mould has two sides detachable which can be attached to create the different size of beam by bolted connection. Four types of metal mould, which accommodates different sizes of specimens, given below

Figure 4-9 Photographs of Mould

Prior to the fitting of channels for a particular size of beam to be casted, surface of sheets, channel sections and joints were properly cleaned with wire brush. Bolts were meticulously tightened to prevent the slurry from leaking out of the joints. Inner surface of the formwork was properly lubricated with oil for easy removal of hardened specimen.

$$A1 \text{ Mold} - \begin{cases} A2\ (900{\times}75{\times}225) \\ A1\ (900{\times}75{\times}225) \\ B\ (1000{\times}75{\times}275) \end{cases}$$

$$A2 \text{ Mold} - \begin{cases} D\ (1200{\times}75{\times}375) \\ E\ (1300{\times}75{\times}425) \\ I\ (1300{\times}75{\times}325) \end{cases}$$

$$A3 \text{ Mold} - \begin{cases} C\ (1100{\times}75{\times}325) \\ H\ (1100{\times}75{\times}275) \\ J\ (1500{\times}75{\times}375) \end{cases}$$

$$A5 \text{ Mold} - \begin{cases} 1(400 \text{ x } 75 \text{ x}100) \\ 2(550{\times}75{\times}150) \\ 3(700{\times}75{\times}200) \\ 4(850{\times}75{\times}250) \\ 5(1000{\times}75{\times}300) \\ 6(1150{\times}75{\times}350) \\ 7(1300{\times}75{\times}400) \end{cases}$$

$$A4 \text{ Mold} - \{F\ (700 \times 75 \times 175)$$

Table 4-7 Mould size

4.3.8 Loading and Supporting Plates

A stiff steel spreader beam was used to distribute the load from the machine plate to beam. The Plates had placed at the loading point and at supporting point Over the knife edges were 40 mm diameter roller assemblies placed between 30 mm thick plates. This arrangement allowed free rotation and elongation of the beam. Similar plate is also used as supporting plate.

Figure 4-10 Mould before casting

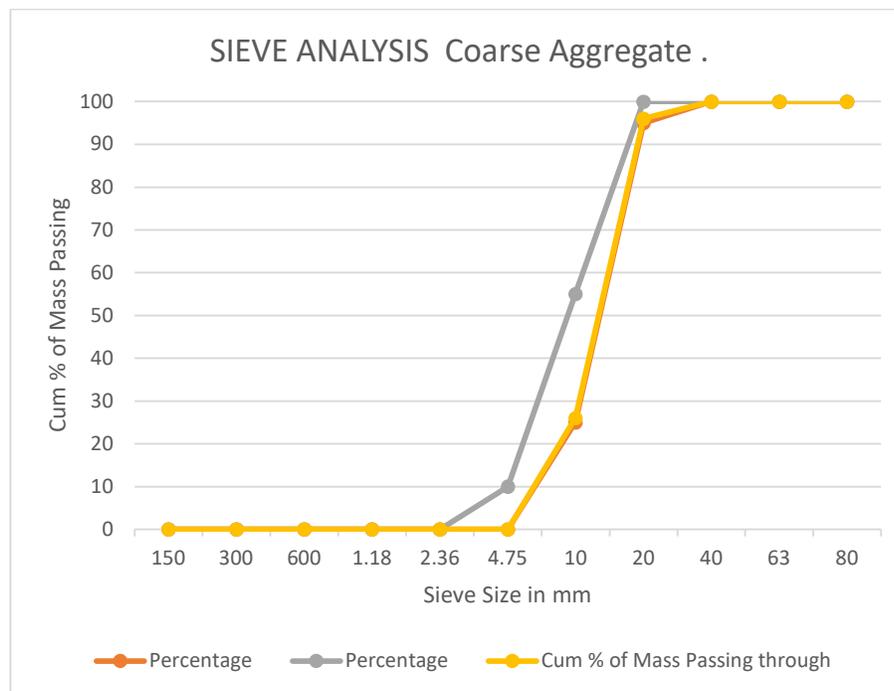Figure 4-11 Loading arrangement for beam

4.4 SIEVE ANALYSIS

Table 4-8 Sieve Analysis Of Coarse Aggregate

Mass of Coarse Aggregate = 2000 gm

Sieve Size	Mass Retained gm	Cumulative Mass Retained gm	Cum % Mass Retained	Cum % of Mass Passing through
80 mm	0	0	0.00	100.00
63 mm	0	0	0.00	100.00
40 mm	0	0	0.00	100.00
20 mm	80	80	4.00	96.00
10 mm	1400	1480	74.00	26.00
4.75 mm	520	2000	100.00	0.00
2.36 mm	0	2000	100.00	0.00
1.18 mm	0	2000	100.00	0.00
600 Micron	0	2000	100.00	0.00
300 Micron	0	2000	100.00	0.00
150 Micron	0	2000	100.00	0.00
Total	2000		678	

Fineness Modulus =Sum of Cumulative Percentage Retained / 100

= 678 / 100 = 6.78

Graph 4-1 Sieve Analysis Of Coarse Aggregate

Table 4-9 Sieve Analysis of Fine Aggregate
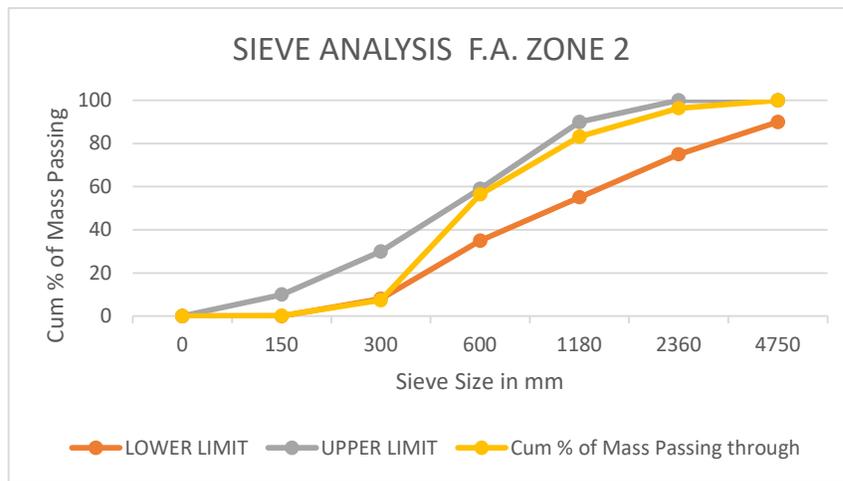
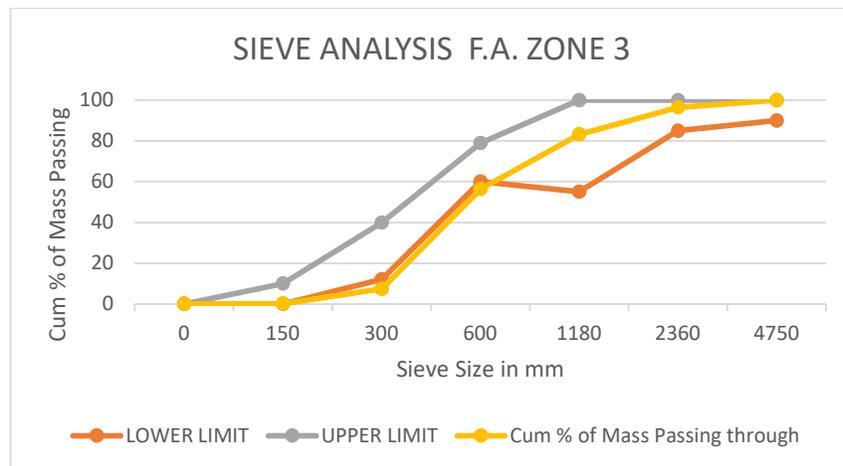| Mass of Fine Aggregate = 1000 gm				
Sieve Size	Mass Retained gm	Cumulative Mass Retained gm	Cum % Mass Retained	Cum % of Mass Passing through
4.75 mm	0	0	0.00	100.00
2.36 mm	36	36	3.60	96.40
1.18 mm	132	168	16.80	83.20
600 Micron	268	436	43.60	56.40
300 Micron	490	926	92.60	7.40
150 Micron	72	998	99.80	0.20
Below 150 Micron	2	1000	100.00	0.00
Total	1000	356.40		

Fineness Modulus =Sum of Cumulative Percentage Retained / 100
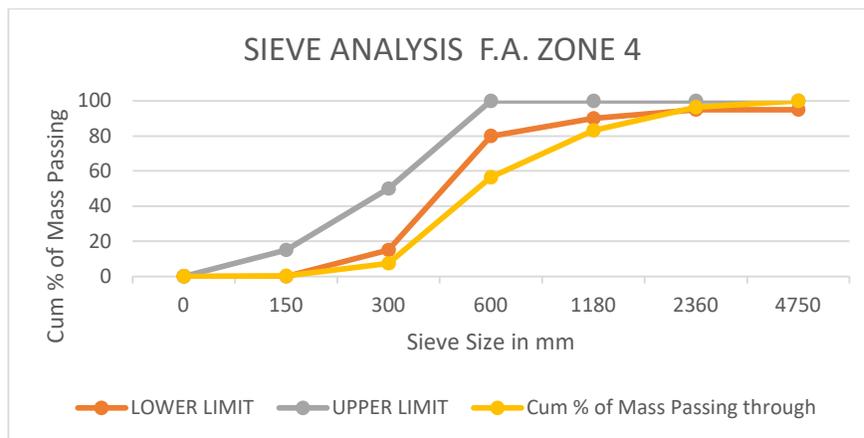
$$= 356.4 / 100 = 3.56$$
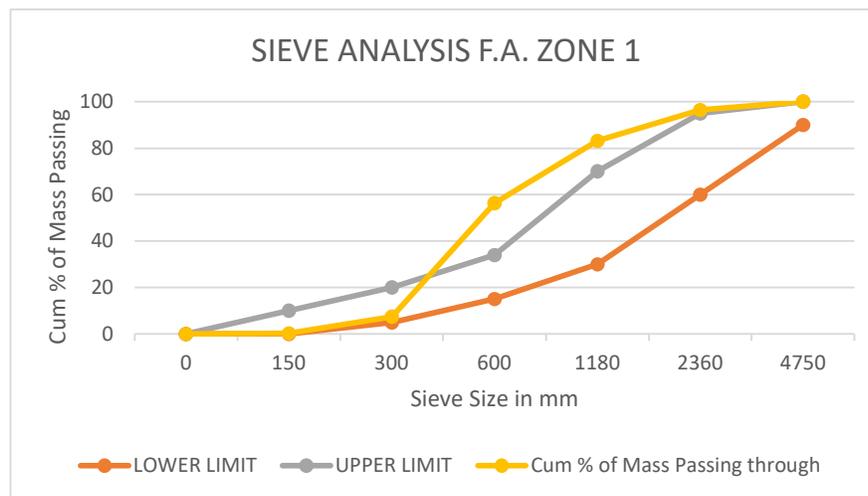
Graph 4-2 Sieve Analysis of Fine Aggregate – Zone-1

Graph 4-3 Sieve Analysis of Fine Aggregate – Zone-2

Graph 4-4 Sieve Analysis of Fine Aggregate – Zone-3

Graph 4-5 Sieve Analysis of Fine Aggregate – Zone-4

EXPERIMENTAL WORK

4.5 MIX PROPORTIONING

Mix proportioning can be defined as the process of selecting suitable ingredients of concrete and determining with the object of producing concrete of certain minimum strength and durability.

Mix Proportion

Stipulations for proportioning:

Grade designation	: M25
Type of cement	:OPC 53 Grade conforming to IS8112
Maximum nominal size of aggregate	: 20mm
Minimum cement content	: 320kg/m^3
Water-cement ratio	: 0.45
Workability	: 100mm (slump)
Exposure condition	: severe
Method of concrete placing	: Pumping
Type of aggregate	: Crushed angular aggregate

a. Maximum cement (OPC) content   : 450 kg/m^3

b. Chemical admixture type   : superplasticizer

c. Type of sand (fine aggregate)   : uncrushed

1. Test data for material:

    a. Cement used   : OPC 53 Grade conforming to IS 8112

    b. Specific gravity of cement   : 3.15

    c. Chemical admixture   :Superplasticizer conforming to IS 9103

    d. Grading of zone of fine aggregate   : II

    e. Specific gravity of Coarse aggregate   : 2.7

    f. Fine aggregate   : 2.7

    g. Super plasticizer   : 1.145

    h. % of chemical admixture   : 0.7%

    i. Water absorption

    • Coarse aggregate   : 0.5%

    • Fine aggregate   : 1.0%

2. Target strength for mix proportion

$$f'_{ck} = f_{ck} + 1.65\,S$$

Where,

f'$_{ck}$ = Target average compressive strength at 28 days,

f$_{ck}$= Characteristics compressive strength at 28 days, and

S = standard deviation.

From Table I, in IS 10262:2009, Standard Deviation, S = 4 N/mm^2.

Therefore, Target strength = 25+1.65 x 4 = 31.6 N/mm^2.

3. Selection of Water-Cement Ratio:

   From Table 5 of IS: 456-2000, Maximum water cement ratio is 0.5

   Based on experience, adopt water-cement ratio as 0.45

   0.45 ≤ 0.45 hence OK.

4. Selection of Water Content

   From table 4 of IS 10262-2009,

   Maximum water content for 20mm aggregate = 186 kg/liter

   (for 25 to 50mm slump)

   Estimated water content for 100mm slump = 186 + (0.06×186)= 197.16 liter

   As super plasticizer is used, the water content can be reduced to 23%

   Hence, the arrived water content = 197.16 × 0.77 = 151.81 liter

5. Calculation of cement content

   Water-Cement ratio = 0.45

   Cement Content = 151.81/0.45 = 337.36 kg/m^3.

   From Table 5 of IS: 456-2000,

   Minimum cement content for severe expose condition =320kg/m^3.

6. Proportion of volume of coarse aggregate and fine aggregate

   From table 3 IS: 10262-2009, Volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.50 = 0.62

   In the present case water-cement ratio is 0.45. Therefore, Volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.10. The

proportion of volume of coarse aggregate is increased by 0.02 (at the rate of -/+ 0.01 for every ± 0.05 change in water-cement ratio). Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.45 = 0.63.

For pumpable concrete this value should be reduced by 10%

Volume of coarse aggregate = 0.63 × 0.9 = 0.567

Volume of fine aggregate = 1- 0.567 = 0.433

7. Mix Calculations:

The mix calculations per unit volume of concrete shall be as follows,

a. Volume of concrete $= 1m^3$

b. Volume of cement $= \dfrac{\text{Mass of cement}}{\text{specific gravity of cement}} \times \dfrac{1}{1000}$

$= \dfrac{337.36}{3.15} \times \dfrac{1}{1000}$

$= 0.107 \ m^3$

c. Volume of Water $= \dfrac{\text{Mass of water}}{\text{specific gravity of water}} \times \dfrac{1}{1000}$

$= \dfrac{151.81}{1} \times \dfrac{1}{1000}$

$= 0.152 \ m^3$

d. Volume of Chemical admixture

$= \dfrac{\text{Mass of superplasticizer}}{\text{specific gravity of superplasticizer}} \times \dfrac{1}{1000}$

$= \dfrac{2.36152}{1.145} \times \dfrac{1}{1000}$

$= 0.002 \ m^3$

e. Volume of all in aggregate = [a-(b+c+d)]

$= [1- (0.107+0.152+0.002)]$

$= 0.739 \ m^3$

f. Volume of Coarse Aggregate = e × volume of coarse aggregate × Specific Gravity of coarse aggregate×1000.

$= 0.739× 0.567 × 2.7 × 1000$

$= 1131.37 \ kg$

g. Volume of fine aggregate = e × Volume of Fine aggregate × Specific Gravity of fine aggregate×1000

$= 0.739×0.433 × 2.7× 1000$

= 836.99 kg

In addition to this, polypropylene and steel fibers were added by 0.7% volume of concrete. 20mm and 10mm coarse aggregates were used in the ratio 65:35. For All beams12% of wastage was considered of total volume of concrete required for 30 beams. Total volume of concrete required for 75beams45 cubes and 30 cylinders was 0.900589 m³. 30 cement bags were required to cast these specimens.

Final concrete mix proportioning

Table 4-10 Final Proportion of Ingredients

Cement		337.36	kg/m³
Water		151.81	kg/m³
Fine Aggregates		836.99	kg/m³
Coarse Aggregates		1131.37	kg/m³
	20mm	735.39	kg/m³
	10mm	395.97	kg/m³
Admixture		2.36	kg/m³
W/C ratio		0.45	
% Fibers		0.7	

4.6   MIXING, CASTING AND CURING

4.6.1 Mixing

Calculated quantities of concrete ingredients accumulated to prepare desired quality of concrete. As per IS Code 10262 – 2009 Concrete grade M25 prepared in laboratory depending upon the quantity of concrete required per one day to cast different size of moderate deep beams. Aggregates to be used were in saturated surface dry condition and free from dirt, dust and foreign materials. OPC 53 grade of cement was used in this casting and kept in dry condition to avoid moisture absorption and formation of lumps. Mixing can be done either manually by hand mixing or by mechanical devices called MIXERS. Here in this experimental work, mixing technique adopted was hand mixing. Dry materials, coarse aggregates (20:10 mm – 65:35 %) and fine aggregates, were thoroughly mixed in rotating drum of portable concrete mixer.

In the mixing procedure, care should be taken while adding ingredients regarding the amount of material to be added at a time in a mixer. Half of the coarse aggregates and fine aggregates were mixed for 1 minute in rotating drum while remaining half were added then after. When all the dry aggregates were thoroughly mixed, materials were dropped on a water tight platform to add cement and fibers. After this, water, also in predetermined quantity was added gradually while mixing was kept continuous. This process was continued until concrete mix of designed consistency was not obtained. Fresh concrete, thus obtained from this procedure was utilized within 10 minutes and it was free from bleeding and segregation which is the basic requirement of fresh concrete.

Figure 4-12 Dry Mix Aggregate

Figure 4-13 Concrete Mixing

4.6.2 Casting

Three moulds were used to cast the different sizes of beams. Prior to the pouring of fresh concrete, moulds were prepared. Movable Channel sections of the mould was arranged and tightened with bolts as per beam sizes. Longitudinal reinforcement, loading plates and support plates were fixed in the mould considering clear cover (20mm) of the beam to be provided. Proper oiling of the mould was done before the pouring of fresh concrete. Vibrating table was used for proper compaction in place of needle vibrator because of lesser width. Fresh concrete was poured gradually into successive layers along with temping by temping rod. The assembly was kept undisturbed for 24 hours to get it hardened. On the next day, formwork was removed with utmost care. 6 cubes

and 4 cylinders were also casted for each composition to measure strength at 7 days and 28 days.

Figure 4-14 Fresh concrete poured in   Figure 4-15 Curing Tank
Formwork

4.6.3 Curing

To achieve proper curing, a clean water curing tank was used. All the specimens of beams, cubes and cylinders were kept in a fully immersed condition for 28 days.

4.7   PRE-TESTING ARRANGEMENTS

Prior to testing, beams were carried out from curing pond and kept in open atmosphere to become dry for one day. Next day all surfaces were made clean with the help of wire brush, air blower and trowel. Then all surfaces were white washed. This coating acts as thin film which immediately reflects and amplifies the crack induced in concrete. Also the marking and notation of the beam elucidates due to white wash.

4.8   INSTRUMENTS

4.8.1 Universal Testing Machine

All the beams were tested in Universal Testing Machine having 200 tones direct Compression capacity and 100 tones Bending capacity. Machine scale has different loading ranges as follows

- ❖ 0-50 ton with least count of 0.1 ton
- ❖ 0-100 ton with least count of 0.2 ton
- ❖ 0-200 ton with least count of 0.5 ton

Above range of loading can be adopted by attaching equivalent weight at the lever arm of machine scale. Movable platform is available in UTM in which adjustable supports are there to fix the span as per requirement.

Figure 4-16 Photograph of Universal Testing Machine

Figure 4-17 Photograph of Lifting Crane

4.8.2 Lifting Crane

After 28 days of curing period, beams were whitewashed with lime and kept it for drying. To convey the specimens on the sliding trey of UTM, manually operated crane having 5.0ton capacity was used. Horizontal and vertical movement gear assembly of crane provides a comfortable way of transporting specimens.

4.8.3 Digital Vernier Gauge

Crack width at different interval of loading was measured with the help of Digital Vernier Gauge. Least count of the instrument was 0.01mm.

Figure 4-18 Digital Vernier Gauge

4.9   TESTING PROCEDURE

Tests were carried out using a Universal testing machine. All the beams were simply supported with different spans varying from 700mm to 1500mm. Beams were centered on platform and leveled horizontally and vertically to achieve uniform distribution of load. Bubble tube was used to check leveling of specimen. Surface of loading point and support point were cleaned with wire brush to avoid instability of during loading which may create sudden breaking of layer of concrete slurry. To identify the difference between cracked and untracked specimens, photographs were taken prior to applied load of each beam.

Two-point load was applied at loading points for beams A2 to E and three-point load for beams F to J using a series of load stages. The interval of manual readings varied for each beam. At each interval, the loading was halted and all cracks were marked with a black marker and the crack widths were measured using Digital Vernier Gauge. Crack propagation and crack width measured. cracks were marked by a dash line directly on the surface of beams. In Auto CAD drawing of all beams prepare and all crack position is marked as per the loading on the beam. Grid lines were created to mark crack patterns. After all photographs were taken at a particular load interval, the loading process resumed until the next required load stage was reached and the same procedure was followed.