CHAPTER-3

EXPERIMENTAL PROGRAMME

3.1 General

The aim and scope of the present investigation were discussed in the previous chapter. Detailed description about the materials used, specimens tested, testing arrangments, test procedure, etc., are described in detail in the following sections of this chapter.

The object of the experimental programme was to study the ultimate behaviour of reinforced concrete deep beams and moderately deep beams with full depth and half depth fibrous concrete with different percentage of steel fibres by volume of concrete. Here forty beams in all, consisting of plain concrete and fibre reinforced concrete beam with half depth and full depth conditions were tested. Observations were made to find the first cracking load, the ultimate load, modes of failure, crack patterns, deflection and crack widths, etc.

3.2 Description of Test Specimens

Forty beams, simply supported on a span of 600 mm, were tested under two point loads at one third point of the span, with addition of 1% and 1.5% steel fibres by volume having aspect ratio of 100. The width of the web in all the beams was kept 75 mm.

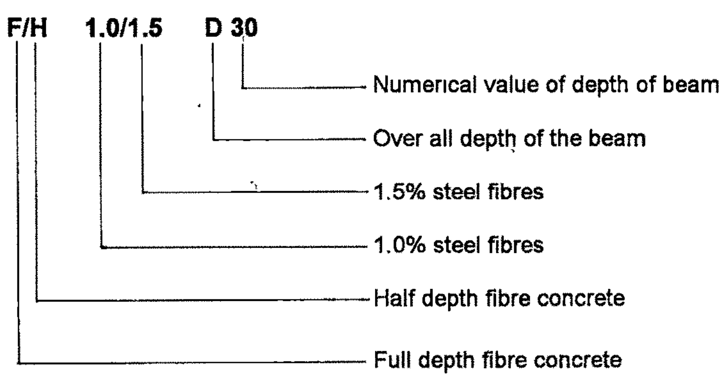
The beams were divided into five series, each series consisting of eight beams with span to depth ratios of 1.0, 1.2, 1.5, 2.0, 3.0, 4.0, 5.0 and 6.0. The overall depths were 600 mm, 500 mm, 400 mm, 300 mm, 200 mm, 150 mm, 120 mm and 100 mm respectively. The first series of beams ("P series") was of plain concrete. The second series ("F 1.0 D 30") was with 1% volume of fibres for full depth of reinforced concrete beam. The third series ("F 1.5 D 30") was with 1.5% volume of fibres for full depth of reinforced concrete beam. The fourth series ("H 1.0 D30") was with half depth of the beam bottom containing 1% volume of fibre reinforced concrete and remaining depth of plain cement concrete. The fifth series ("H 1.5 D 30") was with half depth of the beam from bottom containing 1.5% volume of fibre reinforced concrete and reamining depth of plain cement concrete. Longitudinal tensile steel in each series, upto L/D ratio 3.0, was of one 16 mm diameter round bar. For L/D ratios ranging from 4.0 to 6.0, one 12 mm diameter round bar was used. See **Fig.3.1**.

To prevent bond failure at the support region, the main longitudinal bar was kept longer than the beam. It was threaded at the end. A 75mm x 75mm x 6mm thick plate with a central hole of 20 mm diameter through which the main bar could easily pass was bedded to each end of the beam. The plates at both the ends of beams were tightened with the help of nuts and washers. The supports and loading points of all the beams were adequately reinforced to prevent stress concentration and failure due to local crushing of concrete as seen in **Plate [1]**.

The details regarding overall dimensions, main steel and other reinforcement in each of the five series of beams are shown in **Table-3.1**.

3.3 Notation of Beams

The beams were classified in five series on the basis of quantity of fibres used in both plain and fibre reinforced concrete. For example F 1.0 D30 represents full depth fibre reinforced concrete beam of 30 cm overall depth. H denotes half depth fibre reinforced concrete beam. The notation used is given below and is self-explanatory.



3.4 Materials

Cement

Cement used throughout the experimental work was ordinary portland cement conforming to IS:269-1967. Some of the salient properties of the cement used are presented below :

Property	Value
Normal consistency	33%
Initial setting time	125 minutes
Final setting time	245 minutes
3 days compressive strength	10.4 N/mm^2
7 days compressive strength	15.8 N/mm^2
28 days compressive strength	28.6 N/mm^2

Aggregates

River sand and basalt gravel were used for all experimental work. The fine aggregates i.e. sand,passing through 4.75 mm sieve with a fineness modulus of 2.78 was used for the entire programme. The particle size distribution of the sand used is given below :

SIEVE ANALYSIS FOR FINE AND COARSE AGGREGATE

Fine aggregate		Coarse aggregate	
IS sieve size	% Passing	IS sieve size	% Passing
10.00	100%	40.00	100%
4.75	98.71%	20	95.00%
2.36	92.09%	10	05.00%
1.18	60.63%	4.75	02.88%
0.6	06.63%	2.36	01.48%
0.3	00.23%	1.18	00.98%

The coarse aggregates were crushed in crusher and those having angular shape were used. The available aggregate was separated into two different sizes by sieving and then mixed in the following proportion.

12.5 mm to 10 mm 40% by weight

10.0 mm to 4.75 mm 60% by weight

Water

Clean potable water was used for mixing and curing.

Fibre

Galvanized iron (GI) wires of 0.50 mm diameter and length of 50 mm having aspect ratio of 100 were used as fibres for the entire experimental work. GI wires, available in the form of circular coils weighing about 25 kg, were carefully separated first into smaller coils of about 0.25 kg weight, and tied tightly at diametrically opposite ends. These smaller coils were cut to the required length i.e. according to the required aspect ratio with the help of a shear cutter. Care was taken to see every time that cutting length of fibres were within $\pm$ 0.5 mm of the required length.

Tension tests were conducted on randomly chosen fibre wire in a univsersal testing machine using the range giving a sensitivity of 10 N. The constant load at which there was continuous elongation as indicated by the cross head movement was taken as the yield point load. Total elongation was obtained from the total movement of the cross head and the percentage elongation was calculated with respect to the length of fibre wire between the grips. Any slip of the wire from the grip was visualised from the movement of the pointer. Results of the tests with smooth movement of the pointer only were taken into account in calculating the percentage elongation. The physical and mechanical properties obtained from these tests are shown below.

Properties of the fibre

Diameter	0.50 mm
Yield strength	660 N/mm^2
Ultimate strength	705 N/mm^2
Elongation over a length of 110 mm	15.8% maximum.

Reinforcing steel

All the steel used in beams was plain round bars of mild steel confirming to IS:226-1967. The physical properties were determined in the following manner. Three pieces of 450 mm length of 16 mm diameter and 12 mm diameter were cut at random from the lot and they were tested as per IS:226-1967 recommendations in a 50 tonnes capacity universal testing machine.

The load extension curves for the steel are given in **Fig.3.2** and **Fig.3.3**. The curves had well defined yield points and the value of the yield stress (f_y) was, therefore, taken as the stress corresponding to the load at which a distinct back movement of the load pointer on the testing machine was observed. This was directly recorded on the graph paper fixed on the rotating drum. To prevent crushing at the supports and at loading point, cages of 6 mm diameter round bars were provided. See **Plate [1]**.

3.5 Concrete Mix

Concrete mix was prepared using ordinary portland cement, river sand, crushed gravel, and water. The mix ratio of 1:1.45:3.2 by weight was used.

The water cement ratio by weight was kept constant throughout at 0.5. Properties of concrete mixes are given in **Table-3.2.** The trial mixes were based on a preliminary mix designed by the ACI method for a 28 days strength of 30 N/mm^2.

3.6 Form Work

Forms for all the specimens were prepared from waterproof plywood of 18 mm thickness. Small angles and plates were provided at each corner with clamps by means of nuts and bolts. The moulds were fabricated in the workshop of the Faculty of Technology and Engineering, Baroda. See **Plate [1]**.

3.7 Strain Gauge Applications

After fabircation of the reinforcement, electrical resistance strain gauges were attached to the reinforcing bars as seen in **Fig.3.4**. At the gauge locations, the bar surface was cleaned well to provide a smooth surface. Microns - 120 ohms bakelite base strain gauges with gauge factor 2.0 were used throughout this study. Bonding sides of the strain gauge were thoroughly cleaned with acetone. A paper thin layer of araldite was applied on the cleared surface of the reinforcement. Strain gauge was placed in a proper position. On the side of lead wires, a terminal supplied by the manufacturer was fixed. After araldite got dried out, lead wires and PVC coated copper hook-up wires were soldered to the terminal. A cellotape was stuck on the strain gauge and the bar in order to wipe out excessive araldite and to form a uniform pressure on the strain gauge. The strain gauges were made water proof with successive layers of araldite. The leakage and electrical resistance were checked at various stages. Defective gauges were replaced.

3.8 Mixing

Dry ingredients of the mix viz, coarse aggregate, cement and sand were spread in the loading hopper of the concrete mixer. Afterwards, fibres were sprinkled by hand in dry mix.

Required water was weighed and kept ready. The concrete mixer was started. Dry mixture of aggregate alongwith water was placed in the electrically driven tilting type mixer. The capacity of the mixer is 0.02 m^3. The machine was driven by a motor of 1/3 H.P. working on a 230 volts and 50 cycle AC supply. Statisfactory mixing was possible within 3 minutes by this mixer.

During mixing, "balling up" of fibres due to high aspect ratio was over come by feeding the fibres into the mix in small quantities at a time. When fibres were uniformly spread over the fresh mix, formwork of all beams and moulds were coated with oil. The concrete mix was placed in the moulds and compacted on a vibrating table for about two minutes. Vibration table is of size 1.5 m x 1.0 m and was electrically driven. The frequency of vibration was 6000 cycle/minute. The motor works on 400/440 volts 3-phase AC supply.

3.9 Casting and Curing

Standard steel moulds were used for casting the control specimens viz, cubes (150 mm x 150 mm x 150 mm), cylinders (150 mm diameter x 300 mm hight) and flexure beams (100 mm wide x 100 mm deep x 500 mm long) and direct tension specimen as shown in **Fig.3.5**. Main beam specimen mould was made up of 18 mm thick teak wood at bottom supported on closely spaced 40 mm x 40 mm teak wood plank as stiffners. All the moulds were thoroughly oiled before casting.

Generally three beams, three cubes, six cylindes and, three direct tension spacimens were casted along with the eight main beams. For main test beams the reinforcement was held in place during concreting by passing the main longitudinal bar through the holes provided in the sides of the form work, care being taken to see that the strain gauges were not disturbed. Lead wires were taken out from the top of the mould. All the beams were cast in an upright position in the moulds. On the day following the casting, all the beams, cubes, cylinder and tension specimens were removed from the moulds for curing process.

All the standard control specimens were cast in machined steel moulds and compacted and vibrated in three stages. The excess concrete at the top of the mould was struck off with a wooden straight edge and the top finished smooth by trowelling. The presence of fibres in the fibrous concrete made trowelling some what difficult compared to plain mix. After casting, the main beams and control specimens were marked with oil paint as per their designated notations. During curing process, all the specimens were covered with wet jute bags. The bags were watered daily keeping the beams always in moist condition. The curing for all the test specimens was for at least 28 days.

3.10 Instrumentation and Testing Procedure

All the beams were tested in compression testing machine. The machine is manufactured by VEB WERKSTOP MACHINE, LEIPZIG, East Germany. It is used for the testing of compression and bending strength of building materials especially for concrete elements. The capacity of the machine in direct compression is 200 tonnes and in bending it is 100 tonnes. The machine has a load indicating device on a circular scale disc of outer diameter 400 mm with automatic limit switch. It has different loading ranges given as under:

1. From 0 to 50 t reading interval 0.1 t
2. From 0 to 100 t reading interval 0.5 t
3. From 0 to 200 t reading interval 1.0 t

Possible error of the load indicating value is ± 1%. Load measuring range was adjusted by slip on weights on the pendulum of the load indicating device.

3.11 Deflections

A special stand was developed to measure deflections under the midspan as well as under the loading positions, with the help of dial gauges which could measure the minimum deflection of 0.01 mm. This stand was clamped to the supporting trolley of the testing machine.

3.12 Strain Indicating Bridge

All the strains were measured by digital indicator having measuring range of ± 29000 microns. Accuracy of the instrument was ± 1% for full scale strain. Strains were measured in strain gauges having resistance of 120 ohms with a gauge factor 2.0.

Strain gauges were connected through the newly developed three channel junction box for measuring three strains in three different strain gauges at any particular load. By keeping switch in the off condition for the other two strain gauges, reading of third strain gauge could be recorded.

3.13 Concrete Strain

Surface concrete strains at seven different sections were measured on one vertical face of the beam. Mechanical type Demec gauge with a least count of 0.002 mm was used over a gauge length of 100 mm for the concrete strain measurements. For the purpose of measuring concrete strain 6 mm diameter steel discs with 1.5 mm diameter steel holes at the centre, were pasted on one of the vertical faces of the beam with araldite 48 hours before testing. A sketch showing the position of the discs is shown in **Fig.3.6**.

3.14 Crack Measurements

The first visible crack and further cracks were identified by carefully observing the concrete surface through a magnifying glass. The crack widths were measured using hand held microscope with a least count of 0.025 mm. Plate [2] shows the arrangement of the experimental set up.

3.15 Preparation of Specimens Prior to Testing

The top of test cylinders were ground smooth and level, a day prior to testing, using emery paper. All beams were white washed prior to testing. Control as well as other specimens were carefully marked for positioning them prior to actual testing. On the soffit of beams three alluminium strips were fixed to make the surface level such that the deflections were properly measured. The strips were fixed to the specimen using araldite adhesive mixture after rubbing the surface with sandpaper and cleaning with acetone. Demec discs were fixed after proper cleaning and rubbing with the sand paper.

3.16 Control Specimens

Control specimens, other than the specimen for cylinder split test,were tested as per the Indian Standard Code IS:516-1959. The cylinder split test (Brazilion test) was conducted as per IS:5816-1970. See **Plate [2]**.

3.17 Testing of Main Beams

All the beams were tested under two point loading. The beams were simply supported with a single span of 600 mm. Beams were centered and carefully leveled horizontally and vertically by adjusting the bearing plates before testing. All beams were tested in the compression testing machine with loading arrangement as shown in **Fig.3.7**. The load was applied at the rate of 0.5 tonnes/minute. The beam surfaces were coated with a solution of plaster of paris to facilitate crack detection and marking.

The beam elevation was divided into seven sections of equal lengths equal to the gauge length of the demec gauge used to measure strains. A 100 mm x 50 mm grid was marked in pencil on the surface of the concrete at different levels. The sections were designated as 1,2 3,...,7 as shown in **Fig.3.6**. At each section, Demec discs were fixed. The beam was mounted on the head of the hydraulic jack. The test specimen was then centered and carefully levelled horizontally and vertically and checked with a spirit level. The test specimen beams were loaded as shown in **Plate [3]**. All the gauges were connected to the measuring bridge through three channel unit. Three dial guages were used to measure the deflection at mid-point and under the loads.

The loading was applied gradually. Strains in steel reinforcement, surface strains in concrete and deflections were taken at regular loading intervals. When the load approached the estimated first cracking load, the tension zones of the beams were carefully examined for possible cracks, through a magnifying glass at every 0.5 t load interval in order to detect the first visible crack. The load at which the first crack formed (W_c) was noted. The length and the stage of loading at which a particular crack had appeared was noted. To distinguish the order of appearence of cracks in a given section, they were marked as A, B, C, D, etc. The width of each crack at every section at different levels was measured using a microscope. The load on the beam was further increased until it reached the estimated ultimate load capacity of that particular beam. At every load stage, the process of detecting and marking the new cracks and measuring it was reported.

The initiation of the tension steel yield was easily seen from the sudden increase in the deflection. After this stage,careful observations were made for ultimate load as precisely as possible. Most of the strain gauges intended to measure the steel strain failed or got damaged immediately after the tension steel started yielding.

After failure of the specimen, the load was removed from the cross head of the testing machine and the beam. The pattern of the cracks were painted with black colour and photographs were taken. See **Plates [4 to 8]**.

TABLE - 3.1

PROPERTIES OF TEST BEAMS AND REINFORCING STEEL

Beam Nos.	D mm	L mm	L/D	a mm	a/D	B mm	Dia. of bar mm	$\in_y$ %	f_y N/mm^2
P60	600	600	1.00	200	0.33	75	-	-	-
P50	500	600	1.20	200	0.40	75	-	-	-
P40	400	600	1.50	200	0.50	75	-	-	-
P30	300	600	2.00	200	0.67	75	-	-	-
P20	200	600	3.00	200	1.00	75	-	-	-
P15	150	600	4.00	200	1.33	75	-	-	-
P12	120	600	5.00	200	1.66	75	-	-	-
P10	100	600	6.00	200	2.00	75	-	-	-
F1 D60	600	600	1.00	200	0.33	75	16	30	328.50
F1 D50	500	600	1.20	200	0.40	75	16	30	328.50
F1 D40	400	600	1.50	200	0.50	75	16	30	328.50
F1 D30	300	600	2.00	200	0.67	75	16	30	328.50
F1 D20	200	600	3.00	200	1.00	75	16	30	328.50
F1 D15	150	600	4.00	200	1.33	75	12	25	368.70
F1 D12	120	600	5.00	200	1.66	75	12	25	368.70
F1 D10	100	600	6.00	200	2.00	75	12	25	368.70
H1 D60	600	600	1.00	200	0.33	75	16	30	328.50
H1 D50	500	600	1.20	200	0.40	75	16	30	328.50
H1 D40	400	600	1.50	200	0.50	75	16	30	328.50
H1 D30	300	600	2.00	200	0.67	75	16	30	328.50
H1 D20	200	600	3.00	200	1.00	75	16	30	328.50
H1 D15	150	600	4.00	200	1.33	75	12	25	368.70
H1 D12	120	600	5.00	200	1.66	75	12	25	368.70
H1 D10	100	600	6.00	200	2.00	75	12	25	368.70

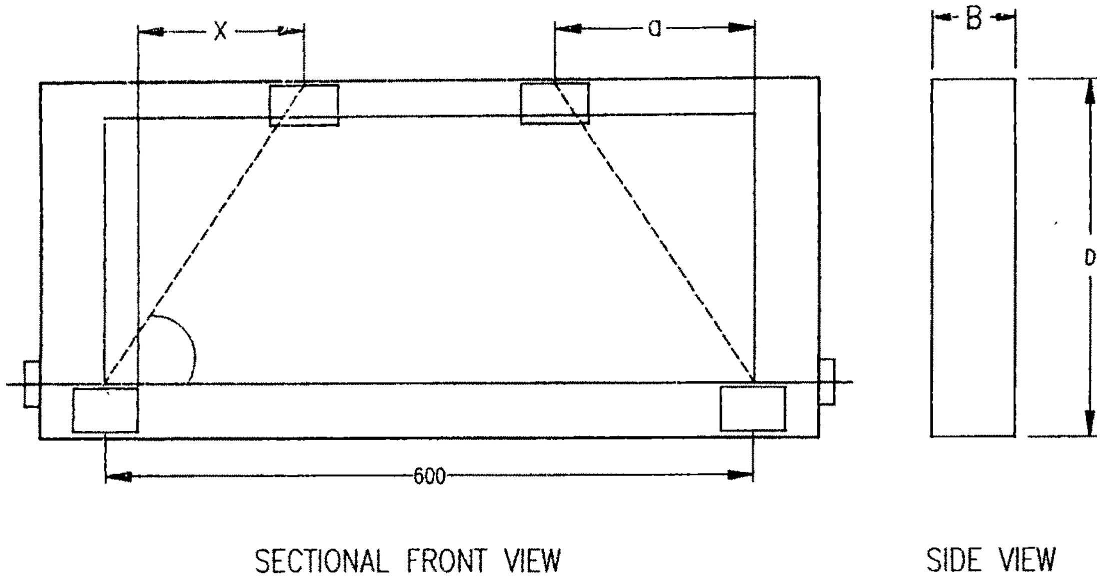
TABLE - 3.1 (Contd.)

Beam Nos.	D mm	L mm	L/D	a mm	a/D	B mm	Dia. of bar mm	$\in_y$ %	f_y N/mm^2
F1.5 D60	600	600	1.00	200	0.33	75	16	30	328.50
F1.5 D50	500	600	1.20	200	0.40	75	16	30	328.50
F1.5 D40	400	600	1.50	200	0.50	75	16	30	328.50
F1.5 D30	300	600	2.00	200	0.67	75	16	30	328.50
F1.5 D20	200	600	3.00	200	1.00	75	16	30	328.50
F1.5 D15	150	600	4.00	200	1.33	75	12	25	368.70
F1.5 D12	120	600	5.00	200	1.66	75	12	25	368.70
F1.5 D10	100	600	6.00	200	2.00	75	12	25	368.70
H1.5 D60	600	600	1.00	200	0.33	75	16	30	328.50
H1.5 D50	500	600	1.20	200	0.40	75	16	30	328.50
H1.5 D40	400	600	1.50	200	0.50	75	16	30	328.50
H1.5 D30	300	600	2.00	200	0.67	75	16	30	328.50
H1.5 D20	200	600	3.00	200	1.00	75	16	30	328.50
H1.5 D15	150	600	4.00	200	1.33	75	12	25	368.70
H1.5 D12	120	600	5.00	200	1.66	75	12	25	368.70
H1.5 D10	100	600	6.00	200	2.00	75	12	25	368.70

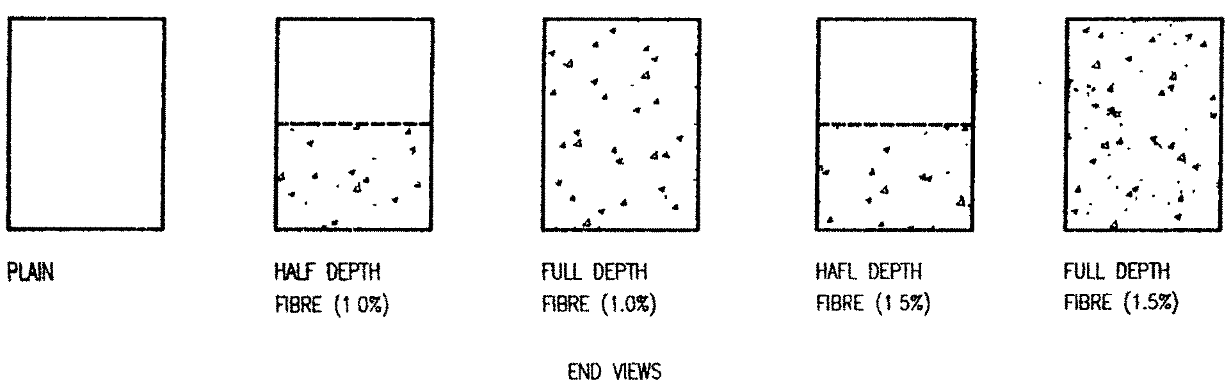
TABLE - 3.2

CONCRETE TEST RESULTS

Beam Series	Cement to sand to gravel by weight	Water/ Cement ratio by weight	Average cube compressive strength f_c N/mm^2	Average Cylinder compressive strength f'_c N/mm^2	Direct tension strength f'_t N/mm^2	Average Cylinder splitting strength f_t =N/mm^2	Bend stress f_r N/mm^2
P	1:1.45:3.2	0.5	34.53	25.82	2.48	32.12	45.7
F1 D 1% Full depth	1:1.45:3.2	0.5	33.84	26.44	3.13	40.20	59.30
H1 D 1% Half depth	1:1.45:3.2	0.5	34.11	26.31	2.58	36.80	60.00
F1.5 D 1.5% Full depth	1:1.45:3.2	0.5	33.34	26.14	3.37	42.30	65.17
H1.5 D 1.5% Half depth	1:1.45:3.2	0.5	34.05	26.62	2.92	38.40	64.34



L	D	B	X	L/D	X/D
600	600	75	125	1.0	0.20
600	500	75	125	1.2	0.25
600	400	75	125	1.5	0.312
600	300	75	125	2.0	0.416
600	200	75	125	3.0	0.625
600	150	75	125	4.0	0.833
600	120	75	125	5.0	1.04
600	100	75	125	6.0	1.25



(All dimensions are in mm)

Fig.3.1 BEAMS OF DIFF SERIES WITH CONVENTIONAL REINFORCEMENT

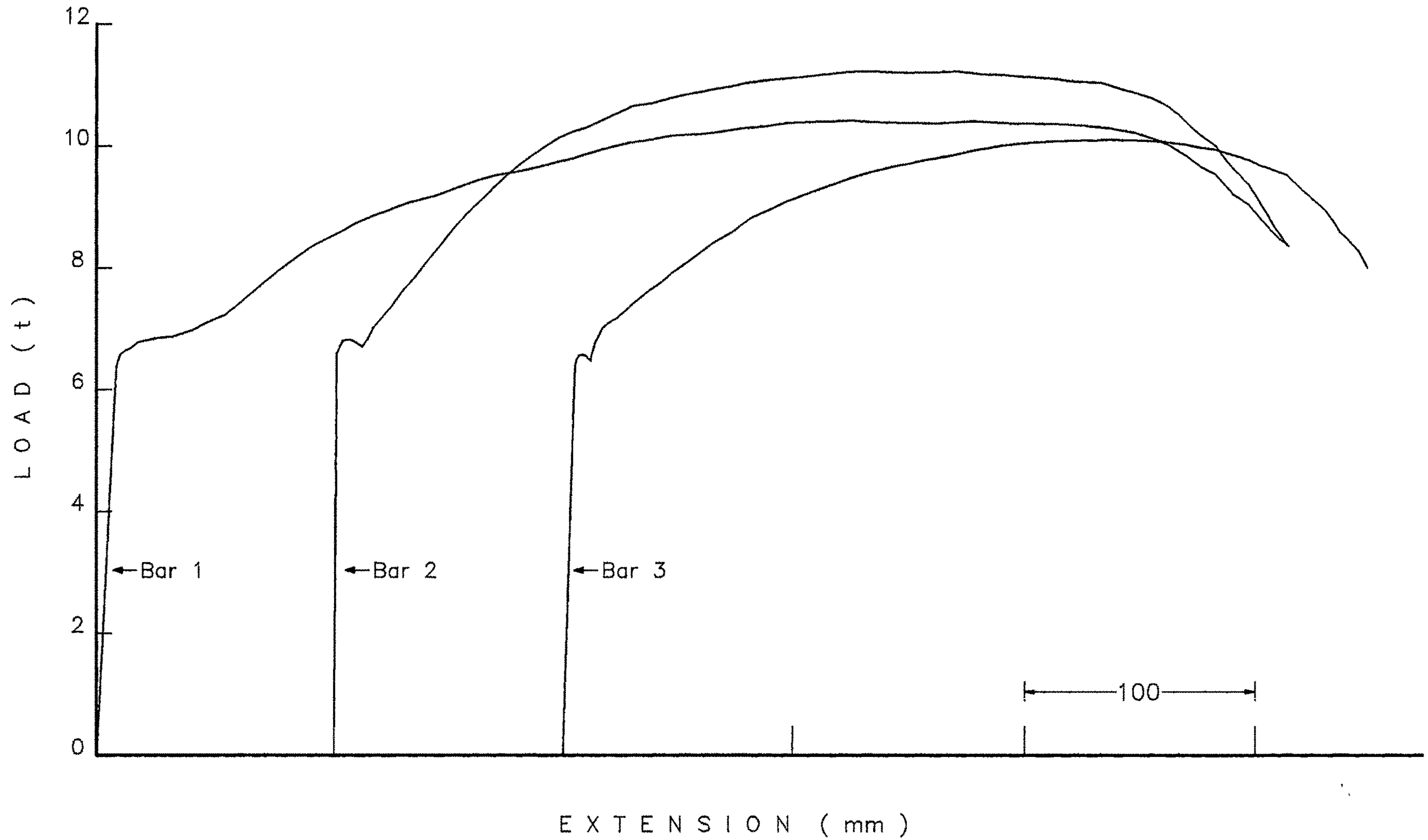


Fig. 3.2 LOAD – EXTENSION CURVE FOR 16 mm DIAMETER BAR

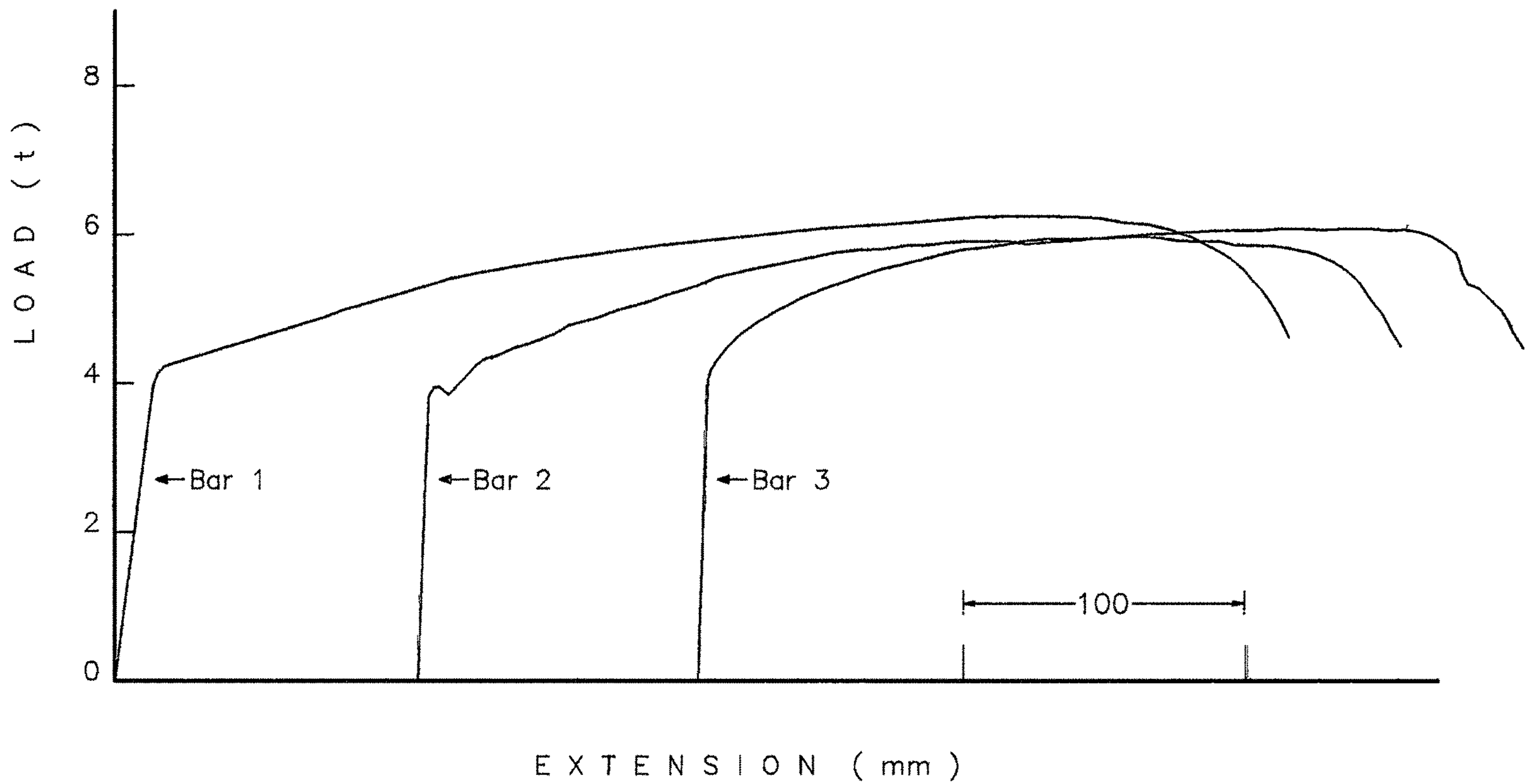


Fig. 3.3 LOAD – EXTENSION CURVE FOR 12 mm DIAMETER BAR

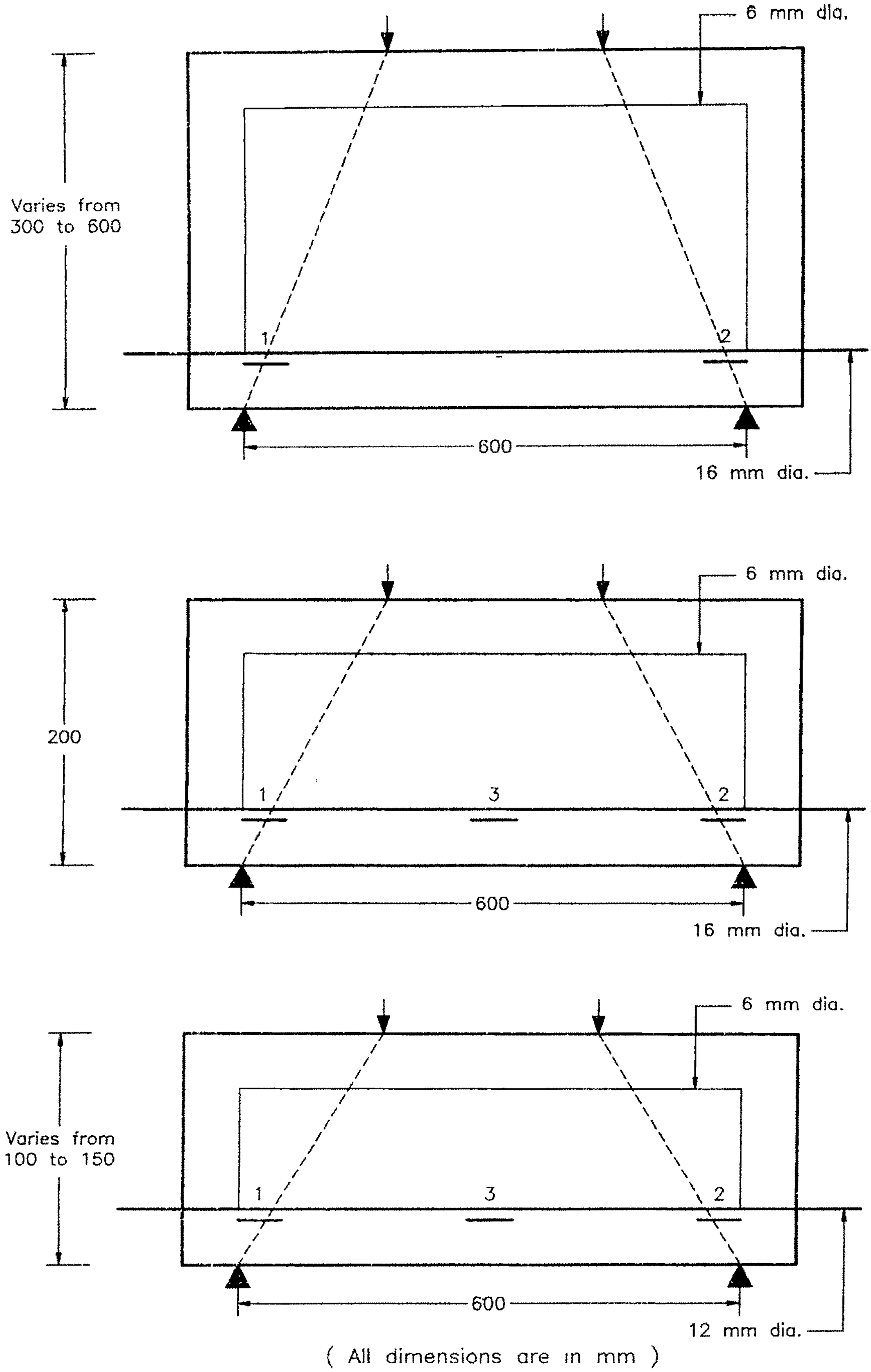
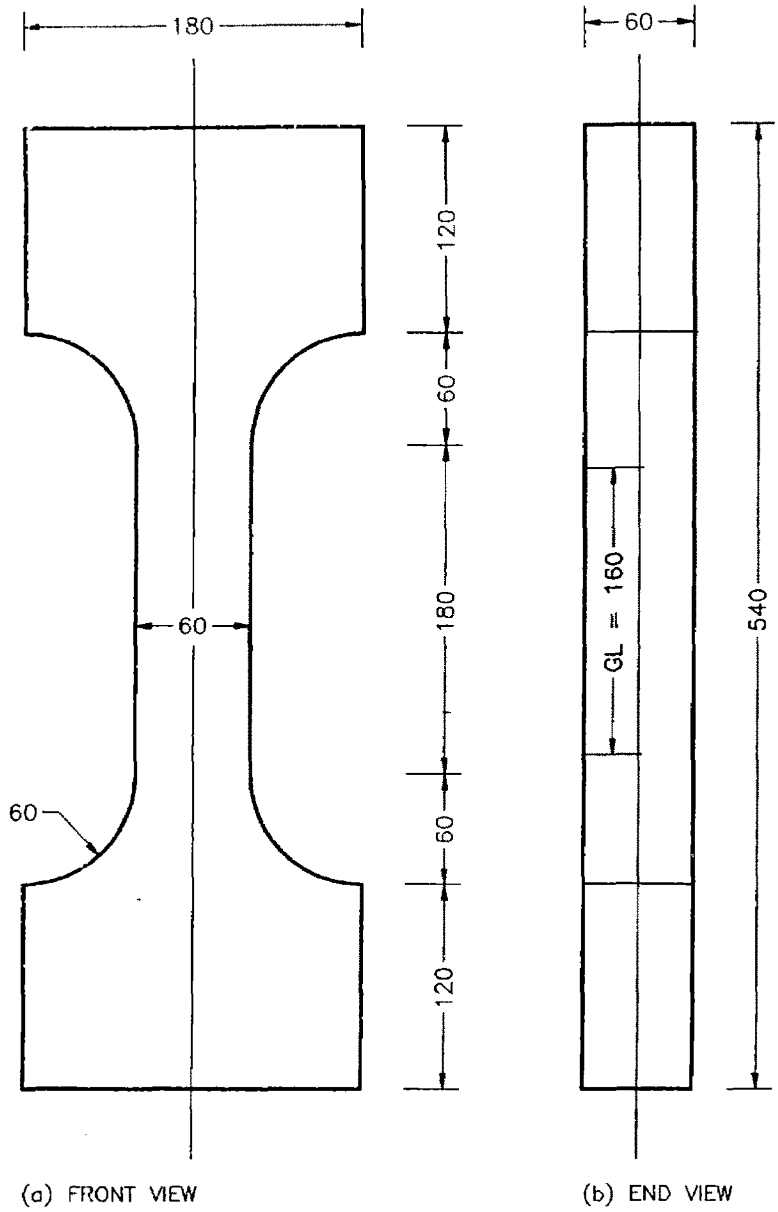


Fig. 3.4 STRAIN GAUGE LOCATIONS



(All dimension are in mm)

Fig. 3.5 TENSION TEST SPECIMEN

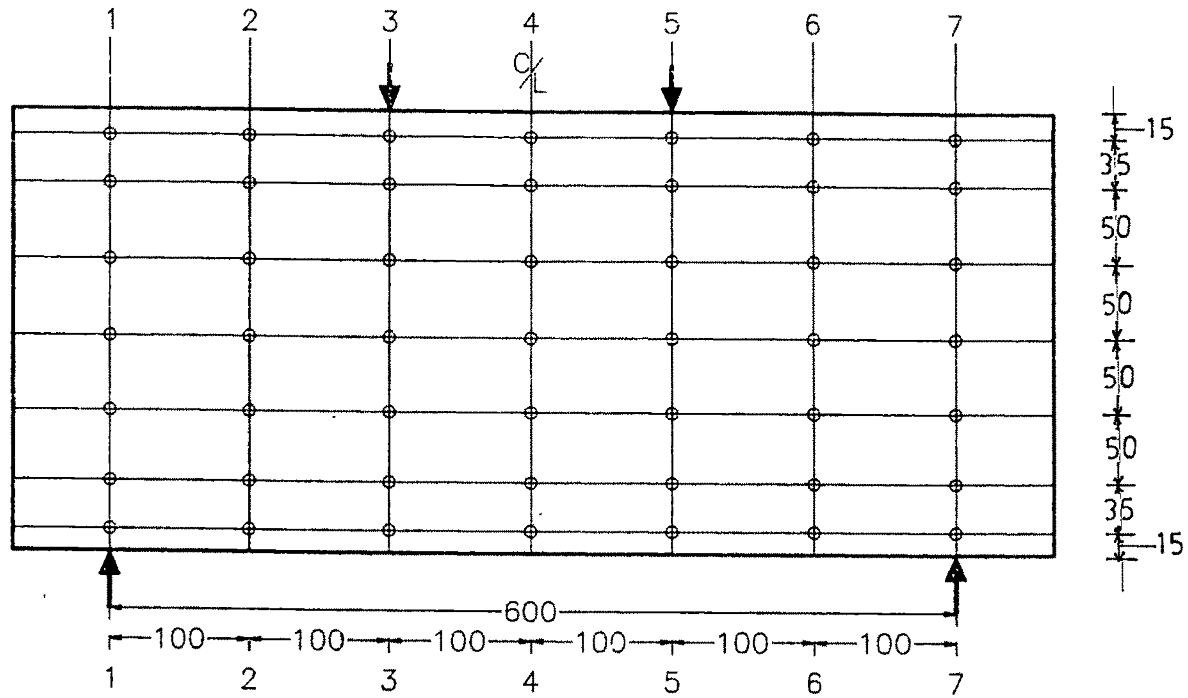


Fig. 3.6 LOCATION SHOWING DEMEC DISCS

All dimensions are in mm

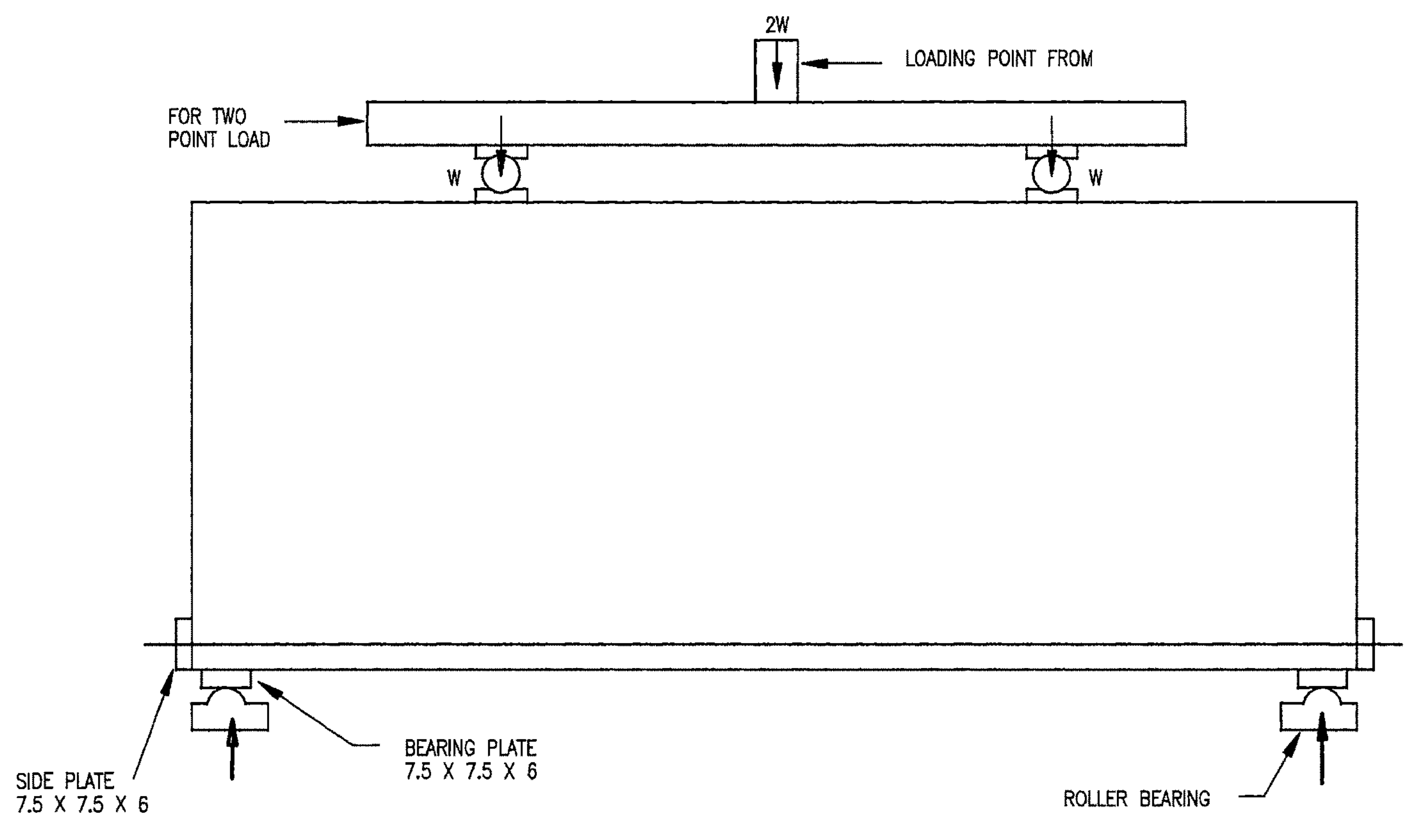


Fig.3.7 TEST LOADING ARRANGEMENT