CHAPTER IV

CONSTRUCTION AND TEST

4.1 Construction

A half scale reinforced concrete model of the prototype was constructed for testing. The form work of the model was made of soft wood and lied with thin ply wood. Since the linear scale of the model was half of the prototype. The area of steel in the model was 25 percents of the value calculated for the prototype. However, the same percentage of reinforcement in the model was maintained as in the original design for the prototype. The detailing of the reinforcement and dimension of the model was shown in Fig. 10 to 13 . The reinforcing bars used were plain mild steel bars and its yield strength was 2400 kg/cm^2. Closed loop stirrups were used and placed in the radial direction. All these stirrups were spaced along the center line of the steps. The upper and lower supports of the model were a 15 cm. reinforced concrete slab, with the plan dimension 40 cm. X 100cm. . All the longitudinal reinforcement steel at the upper and lower end of the staircase were anchored into the supports which were reinforced with closed loop stirrups of diameter 12 mm. at spacing 8 cm. . The lower support slab was cast into mild steel channel sections, which were welded with two steel I-section and a steel channel. These two steel I-section were bolted rigidily to the

laboratory floor. The later steel channel were welded to the two steel column as shown in Fig 19. The upper support slab was also cast into the two steel channels. These two steel channels were welded with the four horizontal steel channels which were support -ed on the four vertical steel columns. The base of the columns were bolted rigidly to the loboratory floor. These four columns were laterally braced with two steel channels and a steel angle against sidesway.

The concrete used in constructing the model had the proportion 1 : 2.3 : 4 (cement : sand : aggregate) by weight and a water- cement ratio of 0.6 . Natural river sand and crushed lime stone of 1½ inch maximum size were used with portland cement type I. The model was continuously cast in six batches. Five specimen of concrete cylinder were obtained for crushing tests and cured by immerging in the water. The model was cured for 21 days by covering with wet sacking. The form work was also removed at 21 days after casting. The average compressive stress from tested specimens at 28 days was 286 kg/cm^2.

4.2 Measuring device

The vertical deflections and horizontal displace- ments in the radial direction were measured by fifteen mechanical dial gauges. An independent square steel frame was built in the inner circle of the helical stair. Steel angles were attached to

the inner square steel frame and projected outward for mounting dial gauges. Eight dial gauges were mounted on the projected steel angle underside along the center line of the staircase to measure the vertical deflections. The horizontal displacements in the radial direction were measured by seven dial gauges. The arrangement of the dial gauges was shown in Fig 14.

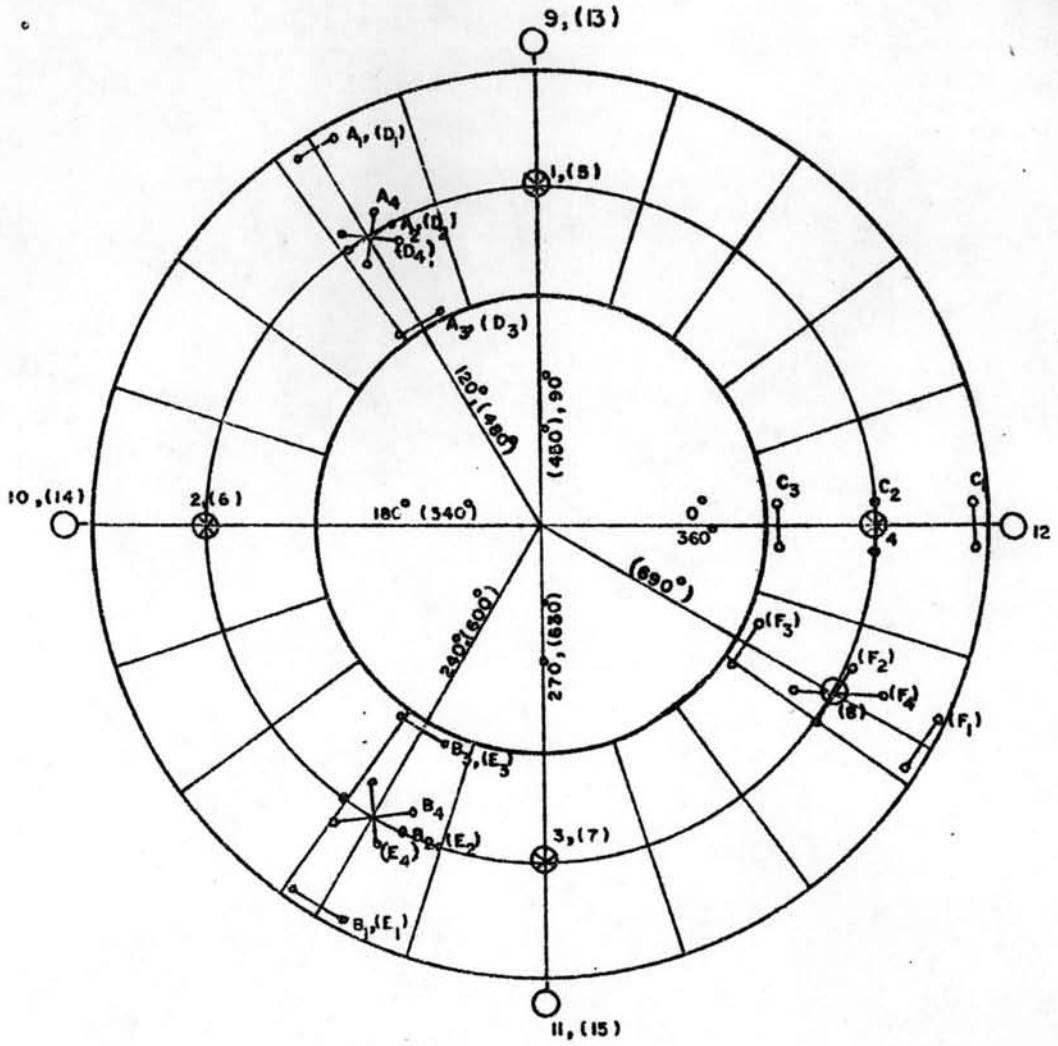
Electrical strain gauges were attached at various sections underside of the staircase for strain measurement. The location of the gauges was shown in Fig 14.

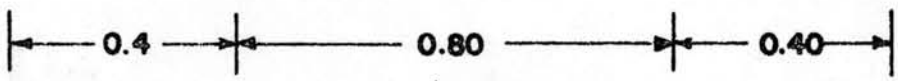
4.3 Testing

The helical stair was tested under uniform load. Prestressed steel wires with length 40 cm. and 80 cm. tied together , each bundle weighing approximately 10 kgs. were used as uniform load. The staircase was loaded in seven cycles and loading schedule was shown in Table 12. At each increment of load, deflections and strains were measured as shown in Table 13 and Table 14. When the load reached 3230.6 kgs. which was over the anticipated ultimate load, all the mechanical dial gauges were removed. At a load of 5313 kgs., many hair cracks were seen at the outer side of the stair and distributed along its length. The final load of the staircase was 7054.6 kgs. However, the staircase did not collapse.

Table 11 : Compressive test of concrete cylinders

Specimen No.	Age (days)	Ultimate load (Kgs)	Compressive stress (kg/cm^2)
1	28	4825	272
2	28	6900	390
3	28	4200	237
4	28	4100	231
5	28	5300	299
Average	28	5065	286





⊗ 1 To 8 = Vertical deflection gauges

○ 9 To 15 = Horizontal deflection gauges (in radial direction)

o—o A_{1-3} To F_{1-3} = Strain gauges (at bottom surface of the stair)

o/ A_4 To F_4 = Strain gauges make an angle 45° to the tangential line of center line of steps

Remark : the number and letter in the brackets represent the deflection gauges and strain gauges at stations coressponding to the angle in the bracket

Fig 14 : Plan of strain and deflection measuring stations

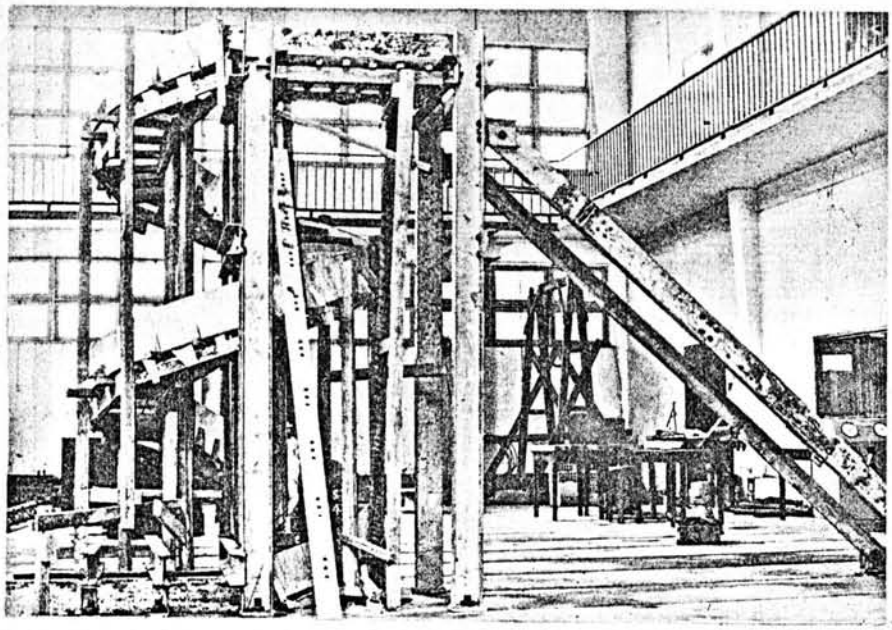


Fig 15 : Formwork and support

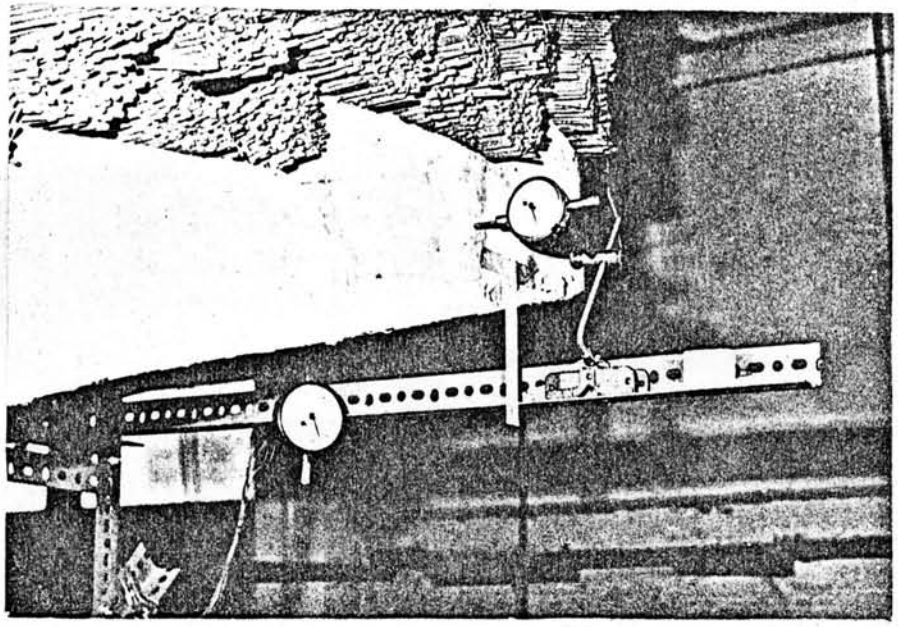


Fig 16 : Typical Measuring Devices

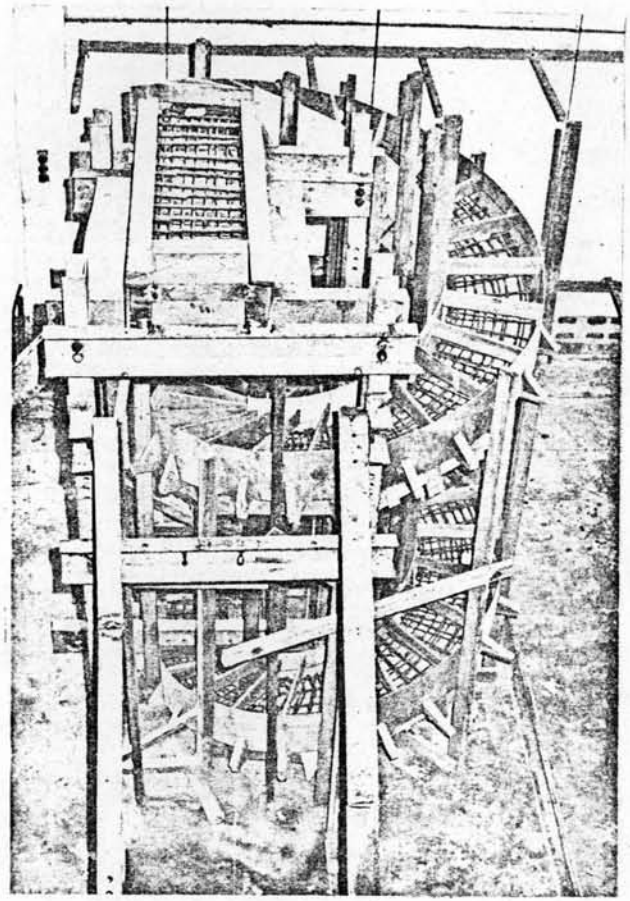


Fig 18 : Arrangement of steel reinforcement in model staircase

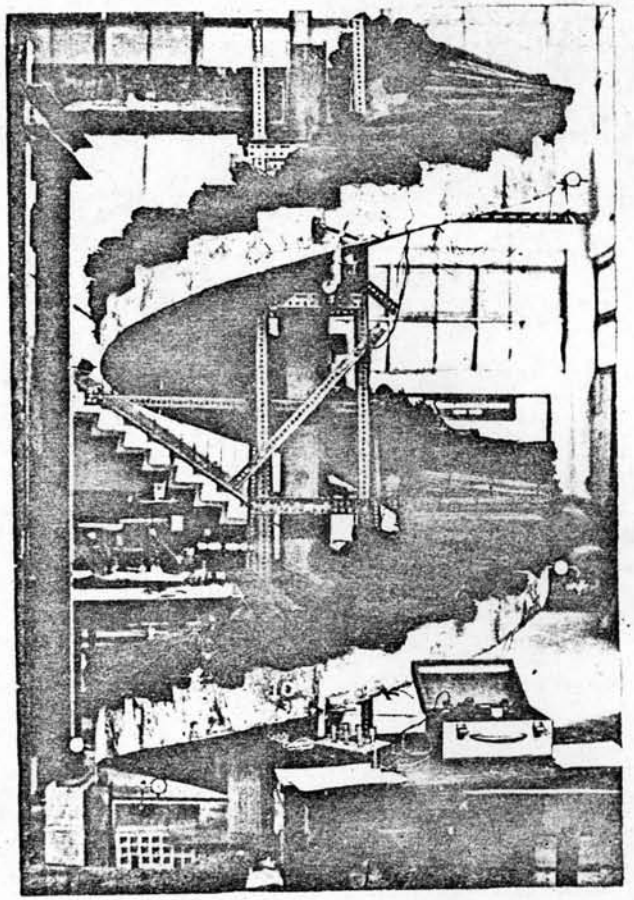


Fig 17 : Model under load

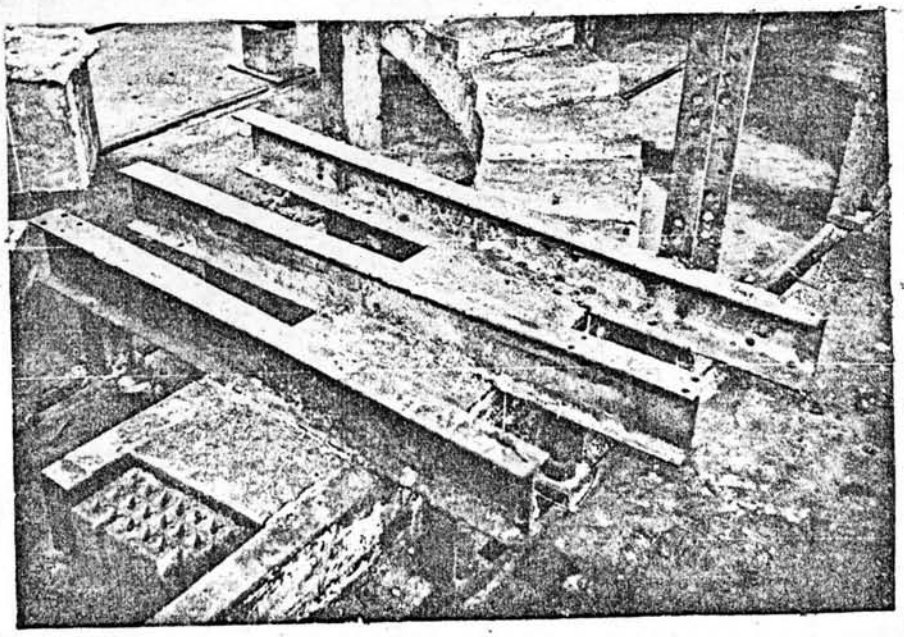


Fig 19 : Fixed end at the lower support

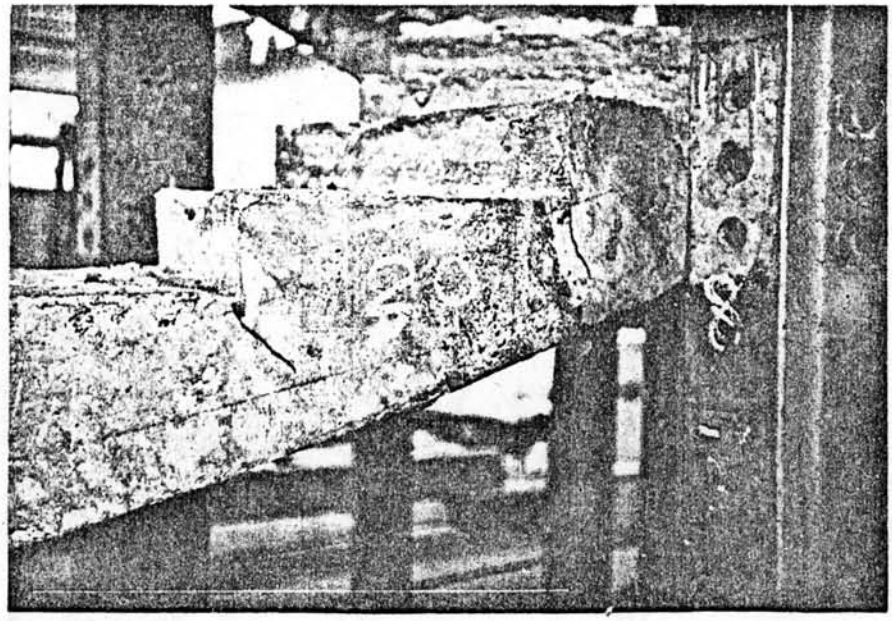


Fig 20 : view of the flexural cracks at mid point of center line of the step of the stairs

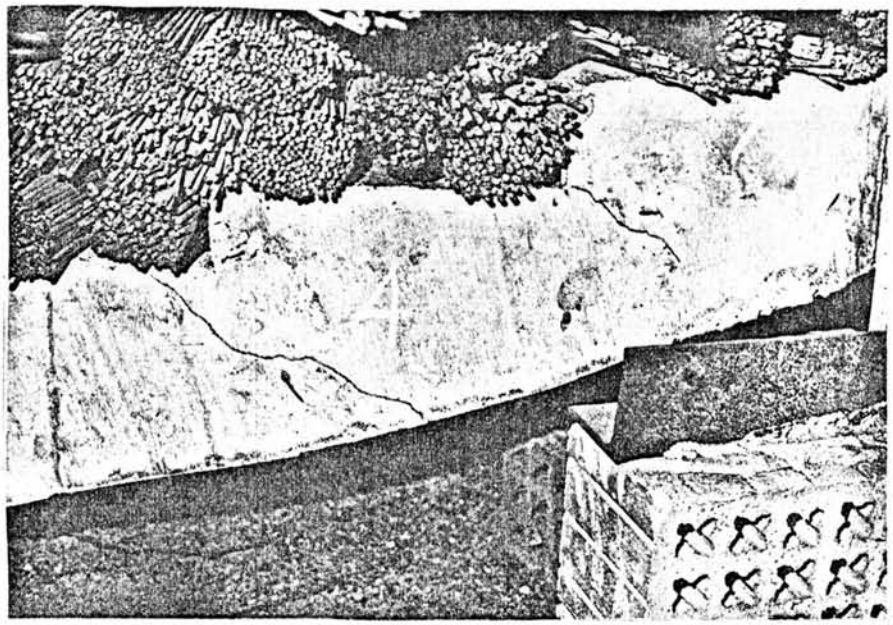


Fig 21 : View of torsional cracks at the outer side of the stairs

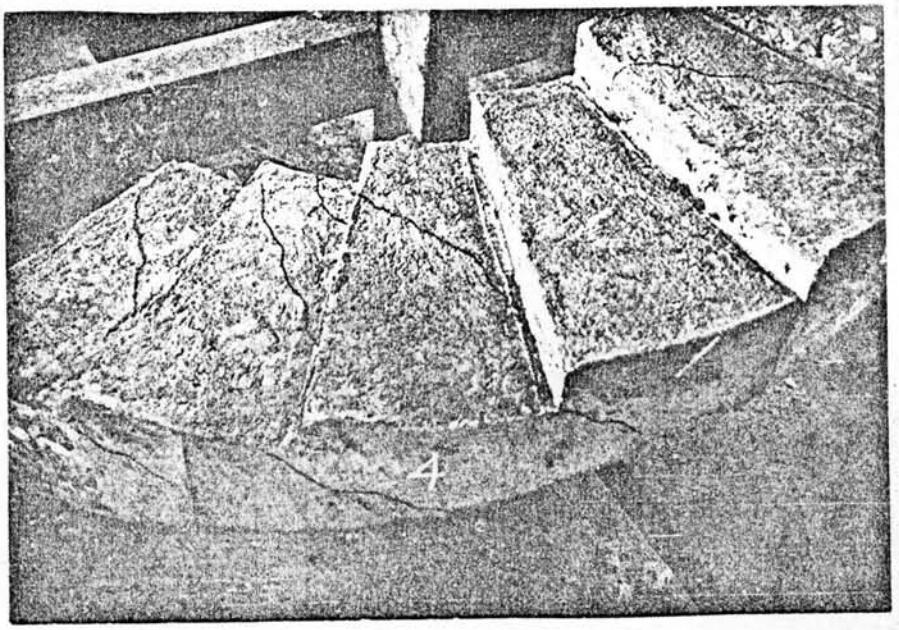


Fig 22 : View of the torsional cracks at the top face of the stairs

Table 12 : Loading Schedule

Step	Cycle of loading						
	1	2	3	4	5	6	7
1		9.7	9.2	18.7	19.0	18.3	95.6
2	8.6	8.7	8.1	19.2	19.0	19.7	95.6
3		8.7	9.9	17.7	19.7	19.2	95.6
4	8.0	9.1	9.8	19.8	18.9	18.5	95.6
5		8.8	9.7	18.0	18.9	18.3	95.6
6	9.7	9.6	9.5	20.3	18.9	19.2	95.6
7		8.9	9.2	18.7	18.5	18.6	95.6
8	8.9	9.0	10.6	18.4	19.4	18.6	95.6
9		8.7	17.9	16.7	18.2	18.6	95.6
10	9.6	9.6	9.7	18.4	18.7	19.4	95.6
11		8.7	9.3	20.0	18.1	18.5	95.6
12	9.0	8.9	18.9	18.3	18.8	19.9	95.6
13		9.5	8.5	18.2	18.7	11.2	95.6
14	8.6	10.0	18.5	20.4	18.3	18.6	95.6
15		9.3	10.0	16.9	19.5	19.2	95.6
16	9.3	9.5	9.7	19.7	17.9	19.1	95.6
17		9.8	20.8	18.4	19.3	18.8	95.6
18	9.5	8.7	9.1	18.8	19.0	21.2	95.6
19		10.0	8.9	15.5	18.5	18.1	95.6
20	9.6	9.6	17.2	18.8	18.7	18.9	95.6
21		10.0	9.3	18.9	18.7	18.7	95.6
22	9.5	9.5	8.7	19.7	20.4	18.2	95.6
23		10.0	17.5	18.0	17.6	19.2	95.6
24	9.0	9.1	9.3	19.8	18.2	18.7	95.6
25		9.0	10.0	18.2	18.3	17.9	95.6
26	8.6	9.1	20.5	18.7	17.4	16.4	95.6
27		8.6	9.6	18.0	19.1	15.2	95.6
28	9.2	9.3	8.8	19.3	18.0	19.6	95.6
29		9.1	17.1	18.2	19.2	19.1	95.6
30	8.8	8.8	9.5	18.6	18.2	19.0	95.6
31		9.5	9.5	19.0	18.1	18.7	95.6
32	9.4	8.8	8.2	17.0	18.7	19.2	95.6
33		8.9	8.9	17.7	18.7	18.4	95.6
34	9.3	9.1	8.7	18.4	18.4	19.5	95.6
35		7.8	9.0	18.5	18.8	19.6	95.6
36	8.9	9.6	8.0	18.2	21.0	20.2	95.6
37		8.8	9.2	18.9	17.8	18.9	95.6
38	8.5	9.4	9.3	16.9	19.3	20.3	95.6
39		9.2	9.5	17.9	19.0	18.7	95.6
40	9.0	10.0	9.8	18.9	17.7	20.1	95.6
Weight(Kgs)	181.0	368.4	444.9	740.2	748.6	747.5	3824.0
Total wt (Kgs)	181.0	549.4	994.3	1734.5	2483.1	3230.6	7054.6

Remark : Tatal working load 900 Kgs

Table 13 : Vertical deflection and horizontal displacement in radial direction

Dial Gauge Number		Total load (Kgs)						
		0	181.0	549.4	994.3	1734.5	2483.1	3230.6
Deflection (1.0×10^{-2} m)	1	0	2.5	7.6	15.2	28.0	40.6	56.0
	2	0	5.8	18.2	40.5	70.5	100.5	145.0
	3	0	10.5	26.5	55.8	96.1	141.0	191.0
	4	0	14.7	39.0	78.0	124.0	175.0	220.0
	5	0	13.5	33.2	68.0	115.3	165.0	197.0
	6	0	8.0	25.5	49.5	85.5	125.2	172.0
	7	0	1.7	6.0	17.7	32.0	48.0	64.0
	8	0	1.0	3.5	7.5	14.6	20.5	25.5
	9	0	-1.2	-3.0	-5.0	-11.0	-18.0	-24.0
	10	0	-5.1	-14.0	-19.8	-35.6	-45.0	-56.2
	11	0	-3.8	-6.4	-23.4	-38.6	-56.0	-63.5
	12	0	2.5	5.0	2.5	0.5	-2.5	-4.0
	13	0	2.0	6.9	16.5	28.5	43.0	56.0
	14	0	5.0	8.9	12.7	18.2	30.3	42.0
	15	0	1.2	2.5	5.0	7.5	10.2	16.5

(Negative for outward horizontal in radial direction)

Table 14: Strain measurement at station A to F

Strain Station		Total load (Kgs)						
		0	181.0	549.4	994.3	1734.5	2483.1	3230.6
Strain 1.0 X 10^{-5}	A1	0	1.5	2.6	3.0	4.2	4.0	4.2
	A2	0	1.0	3.2	4.0	4.5	5.8	6.8
	A3	0	2.0	3.7	4.5	6.8	6.8	9.0
	A4	0	0.2	2.3	5.0	7.0	8.1	11.8
	B1	0	-	-	-	-	-	-
	B2	0	2.0	6.4	13.0	15.6	19.7	22.0
	B3	0	2.7	7.3	11.3	13.9	15.8	18.6
	B4	0	-	-	-	-	-	-
	C1	0	-3.0	-1.0	-3.5	12.0	22.5	30.0
	C2	0	2.2	-2.0	-1.0	9.0	15.0	26.0
	C3	0	-2.2	0	4.0	10.3	12.0	24.0
	D1	0	-3.0	0.5	-2.0	4.0	8.0	16.0
	D2	0	-2.0	-1.0	1.0	5.0	7.5	12.0
	D3	0	1.5	-3.0	-2.0	3.0	3.8	4.0
	D4	0	-1.3	2.0	-3.0	6.0	14.2	19.4
	E1	0	-2.7	0.5	-1.5	-2.5	4.8	9.5
	E2	0	-2.0	-2.0	-2.0	1.5	3.0	2.5
	E3	0	2.0	-3.6	-3.2	0.8	-2.3	1.0
	E4	0	-3.0	-1.5	-1.0	2.0	9.6	20.0
	F1	0	-3.4	-2.8	-2.4	7.8	9.6	12.1
	F2	0	2.0	-2.5	-2.0	3.0	8.3	10.3
	F3	0	-3.4	-0.9	3.0	6.2	11.8	11.1
	F4	0	-2.4	-1.9	-0.6	6.1	14.0	15.4

Remark : Positive for compression and negative for tension

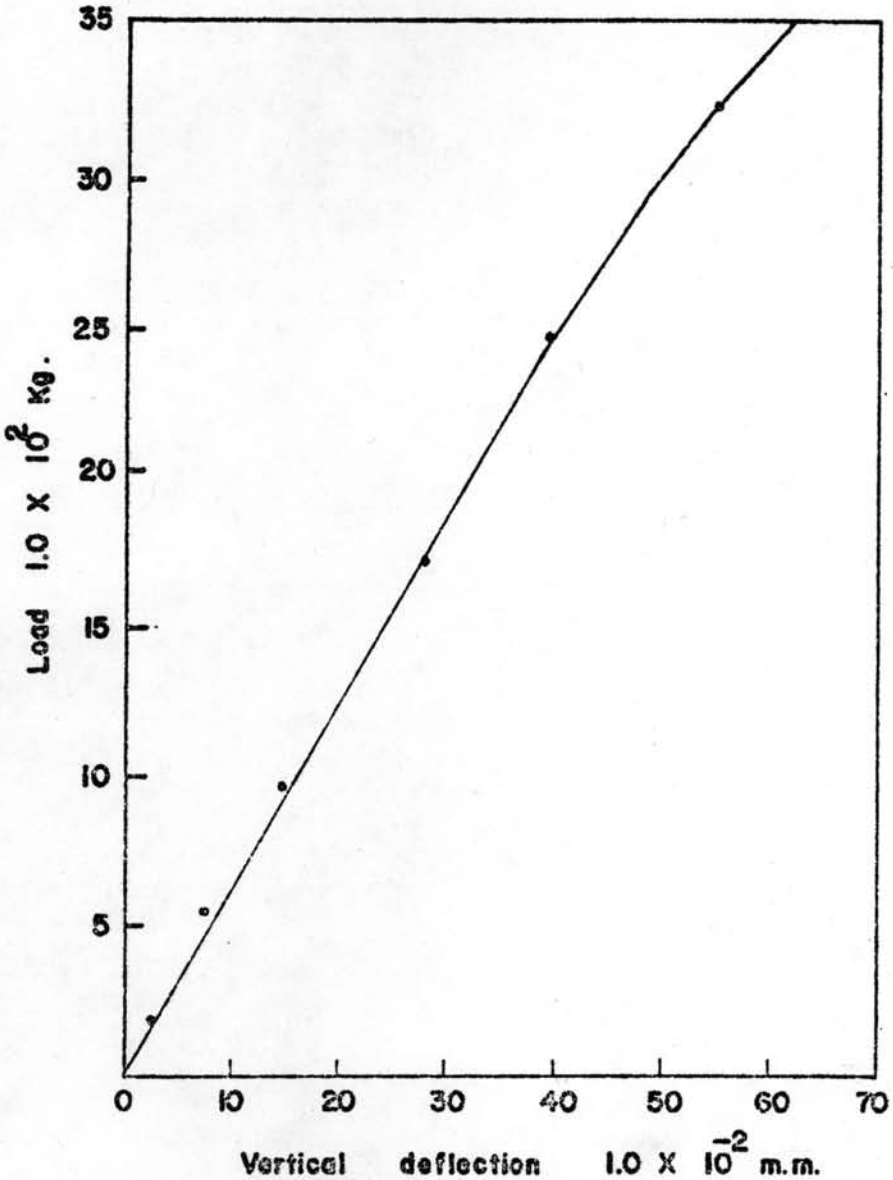


Fig 23: Vertical deflection curve

(Gauge 1)

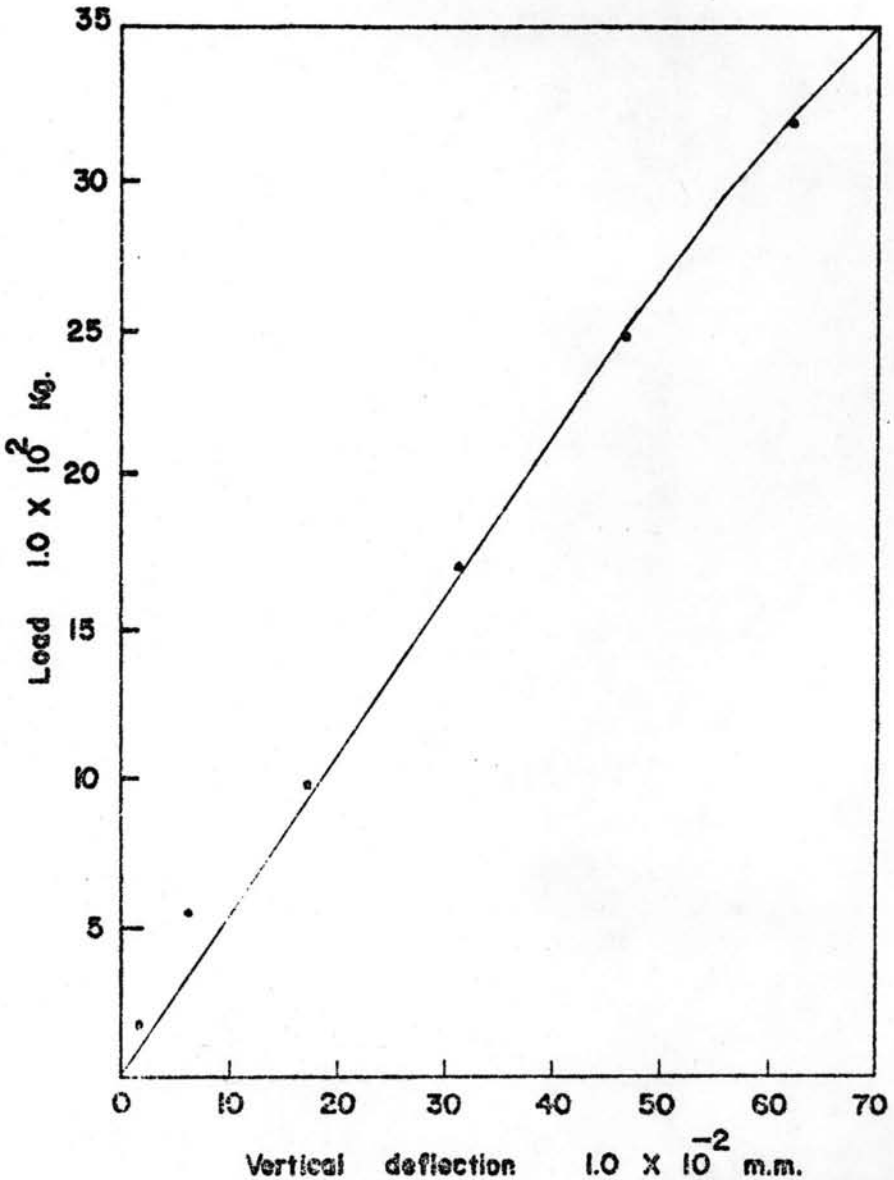


Fig 24: Vertical deflection curve

(Gauge 7)

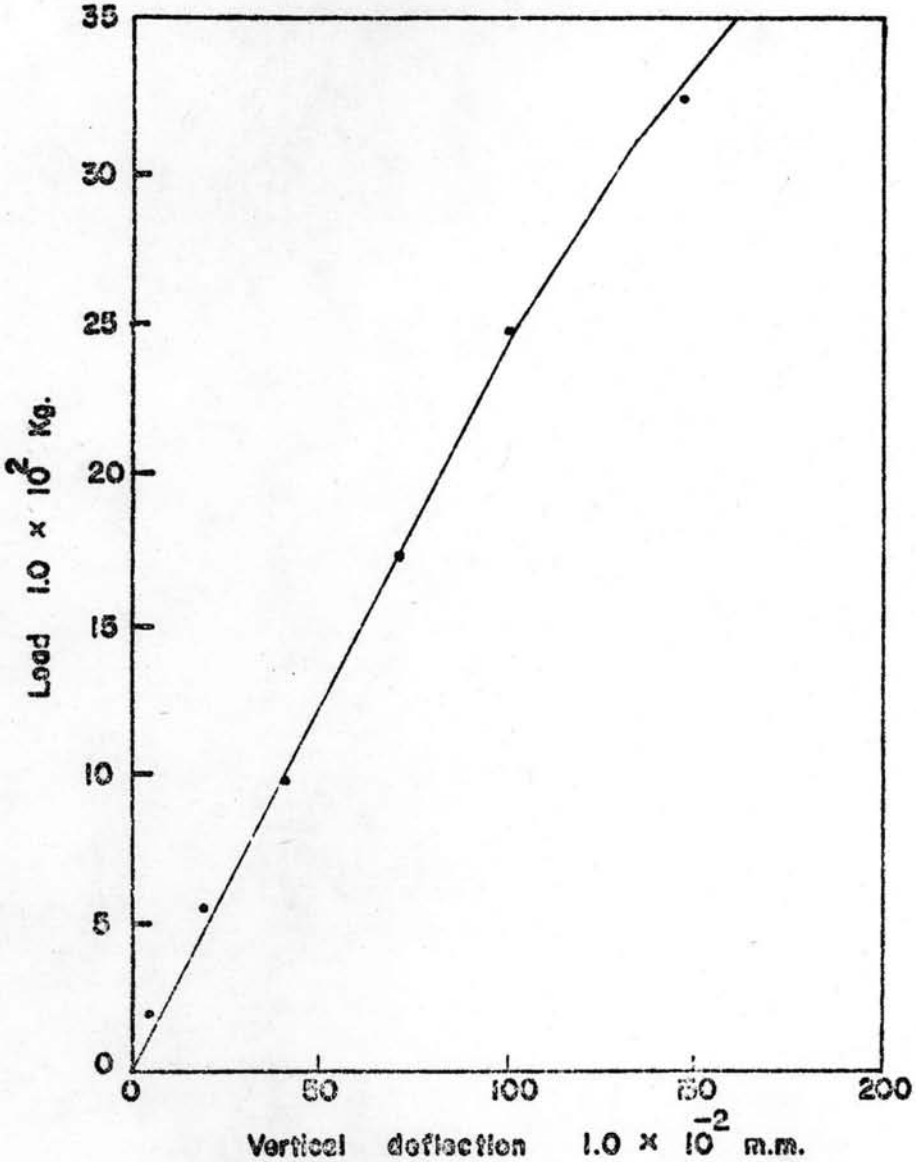


Fig 25 : Vertical deflection curve

(Gauge 2)

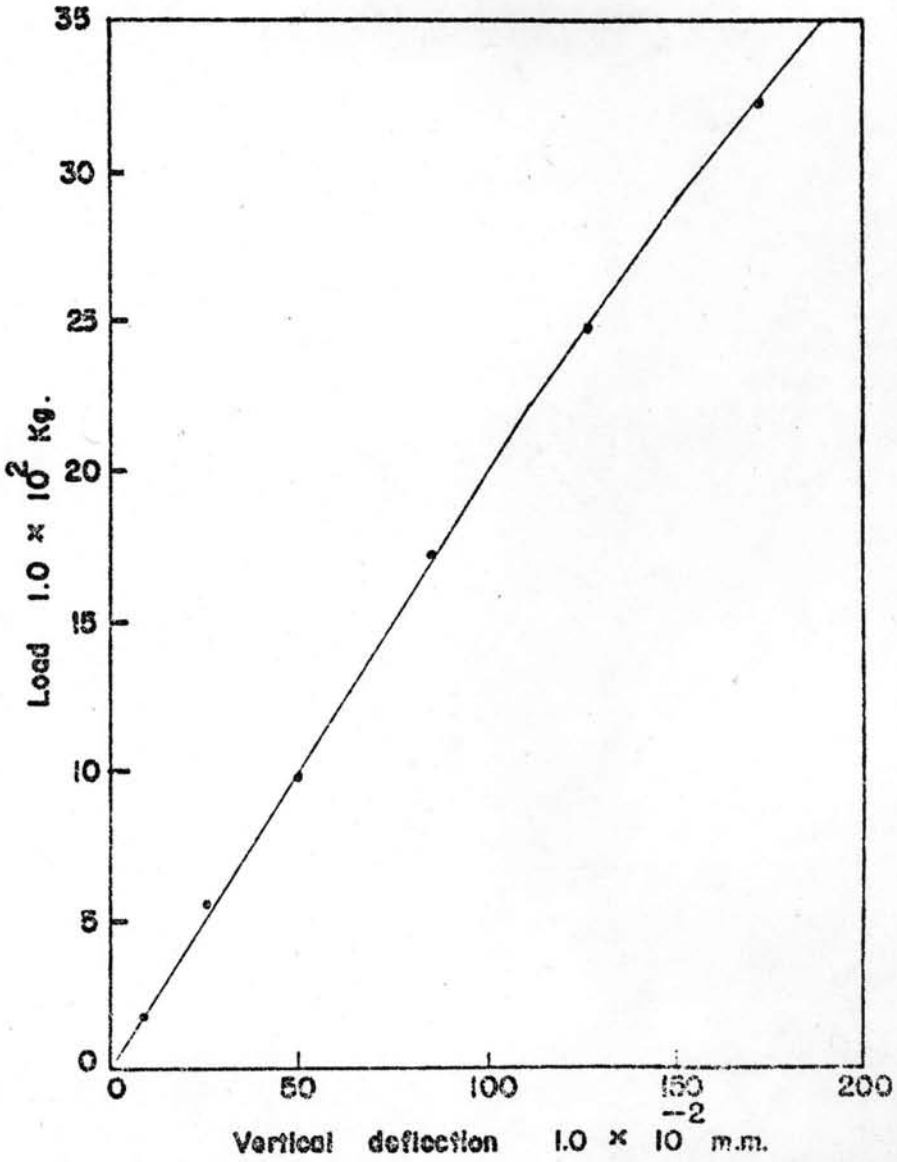


Fig 26 : Vertical deflection curve

(Gauge 6)

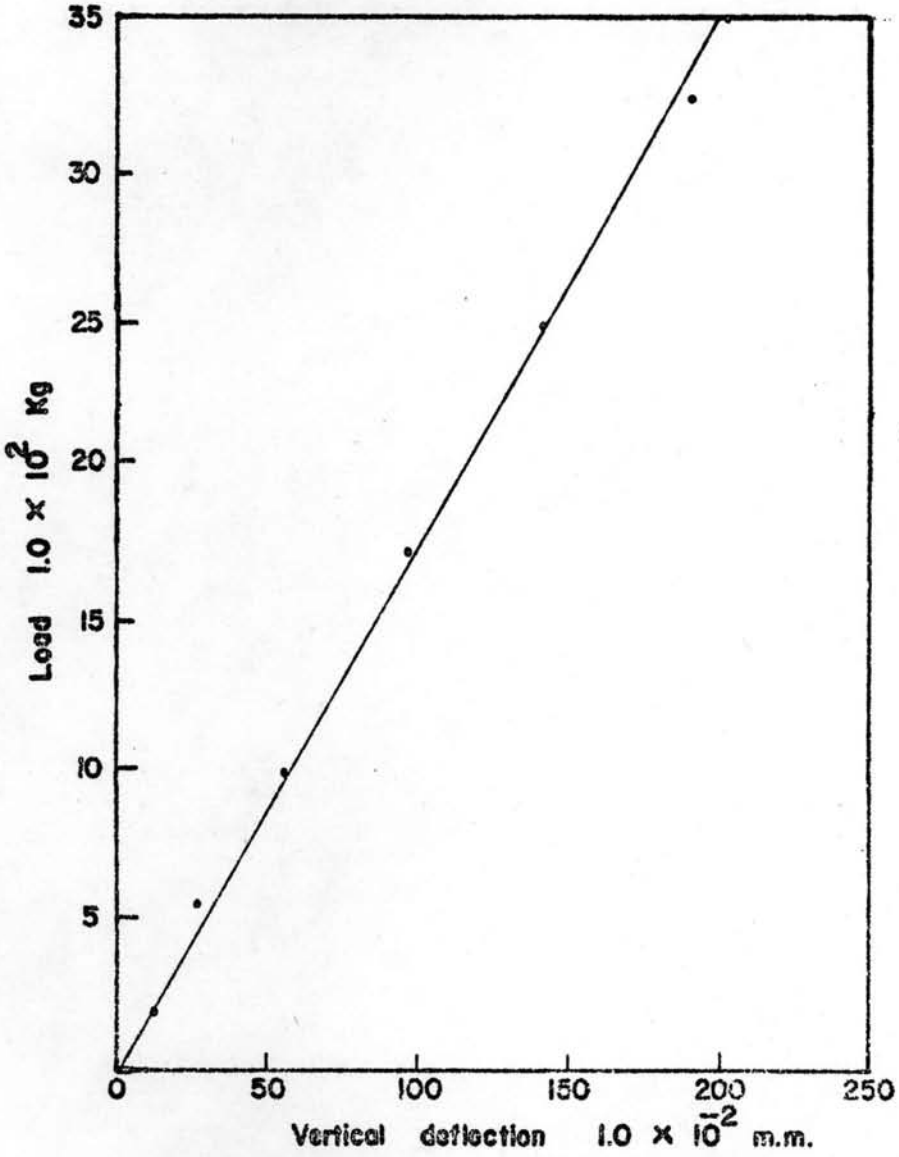


Fig 27 : Vertical deflection curve

(Gauge 3)

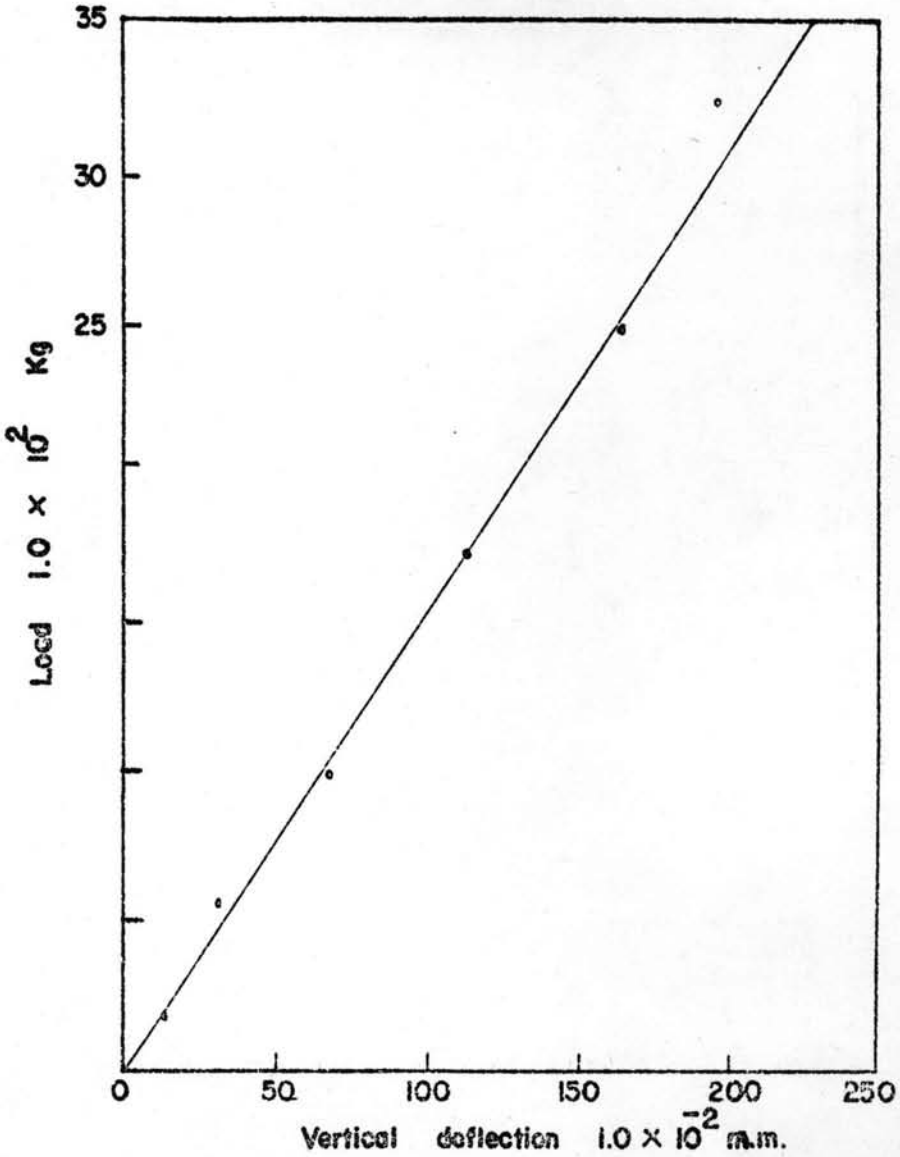


Fig 28 : Vertical deflection curve

(Gauge 5)

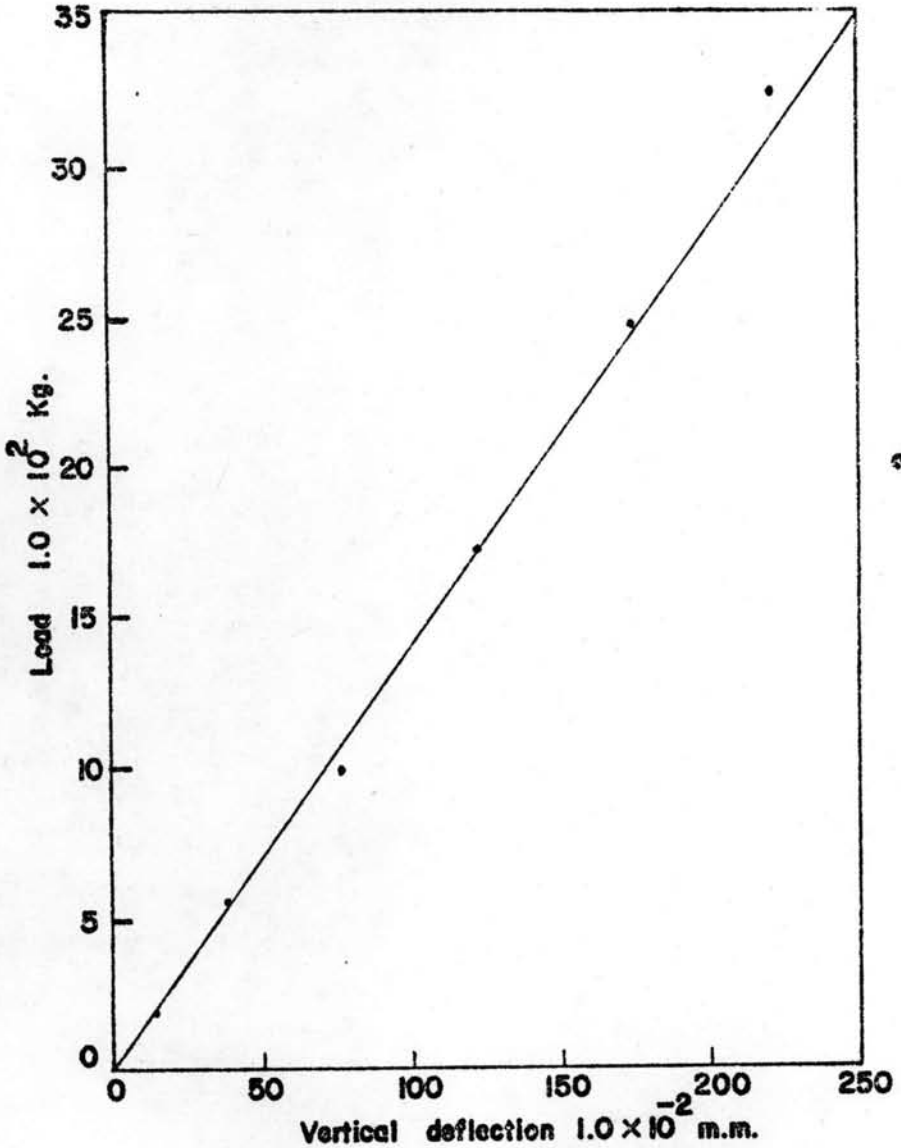


Fig 29 : Vertical deflection curve

(Gauge 4)

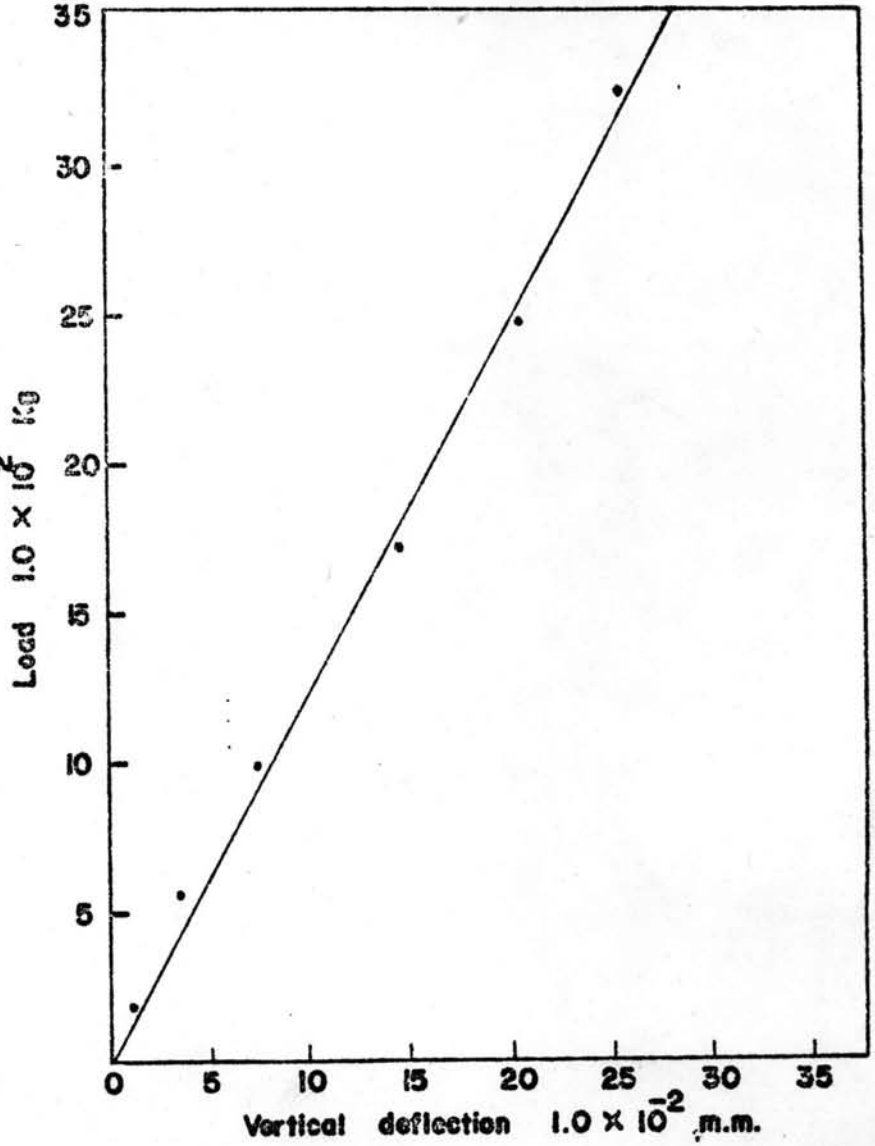


Fig 30 : Vertical deflection

(Gauge 8)

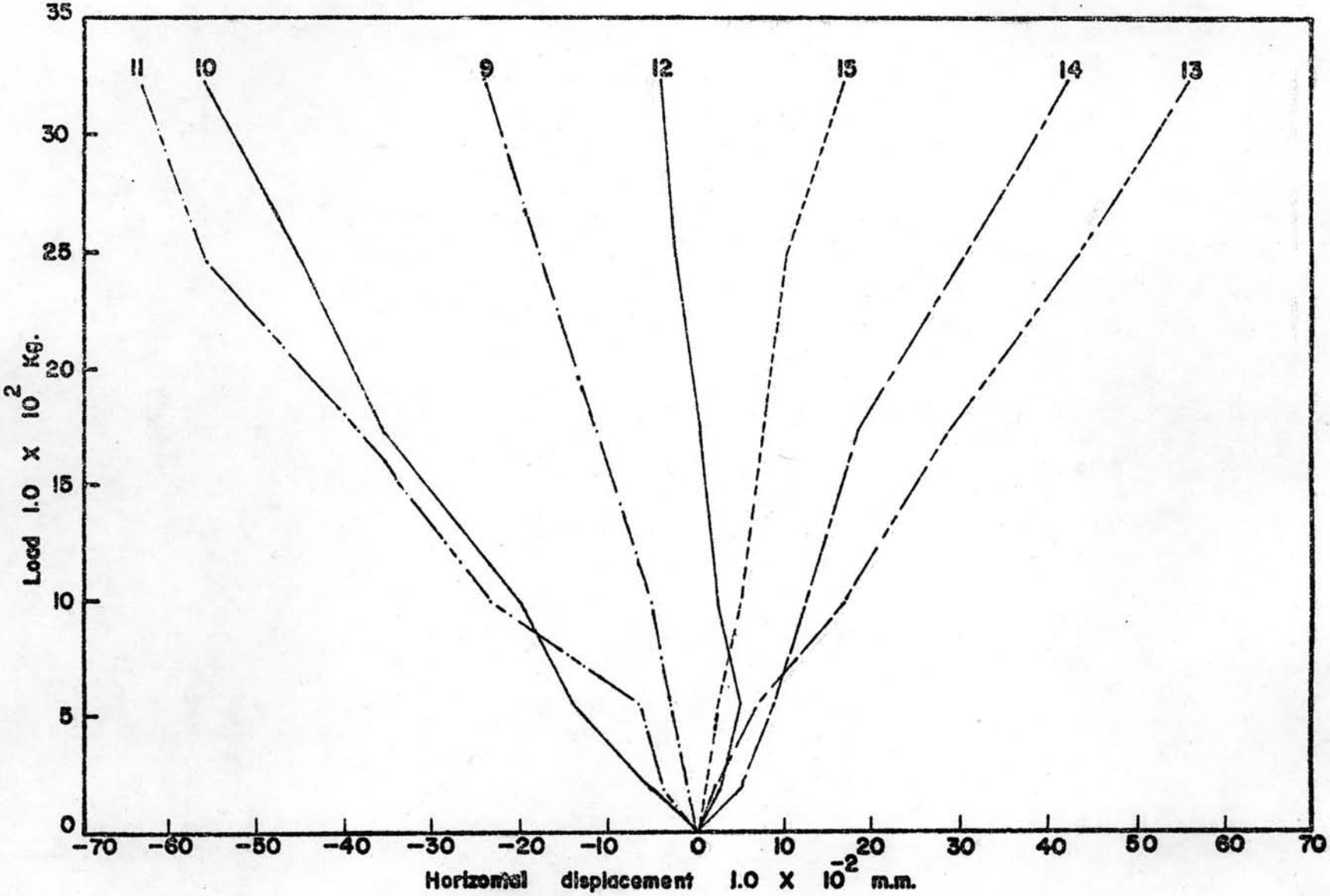


Fig 31 : Horizontal displacement in the radial direction
(As measure at the outer side of stairs)

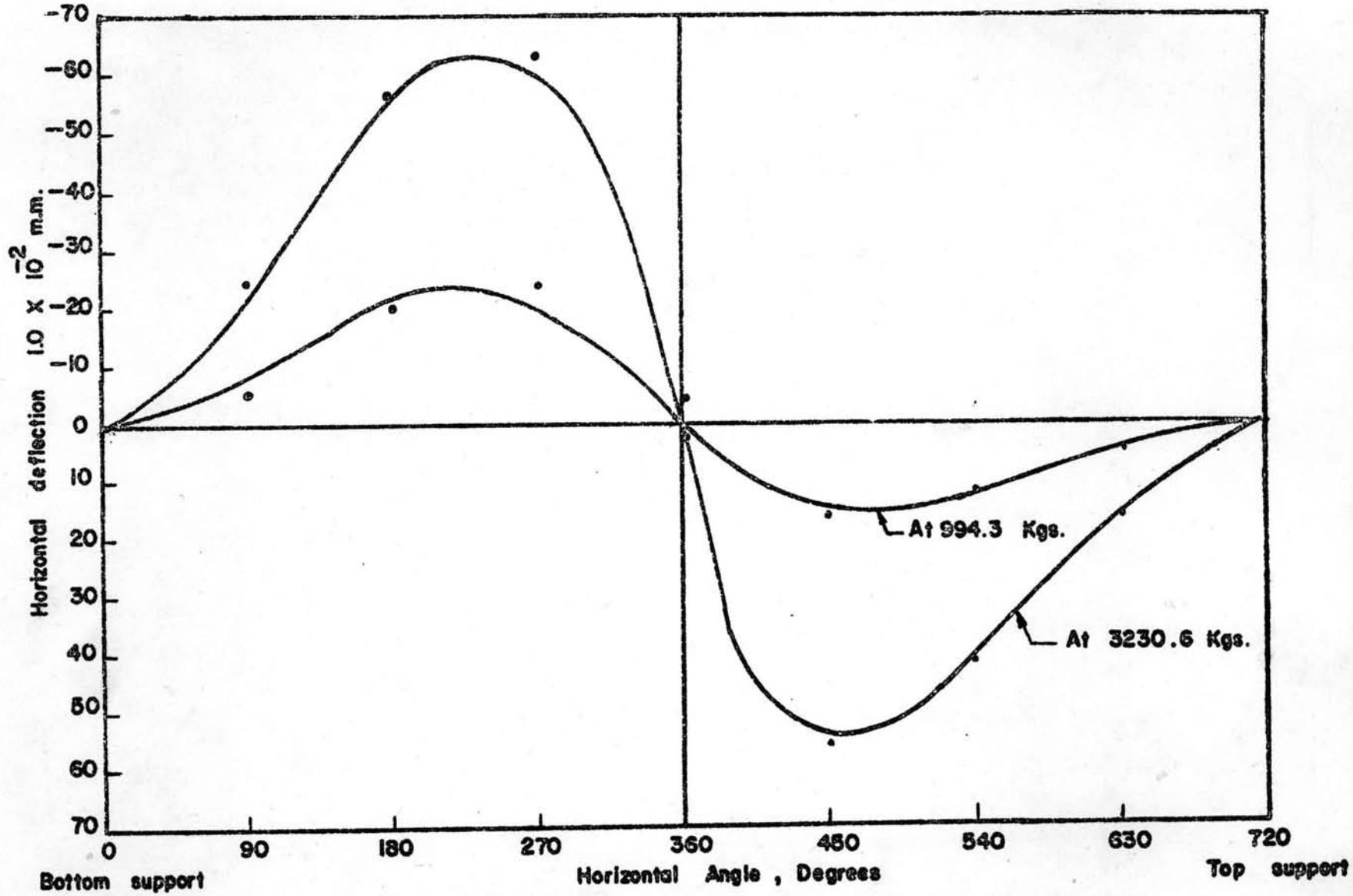


Fig 32 : Horizontal Deflection in the radial direction along the outer side of stair

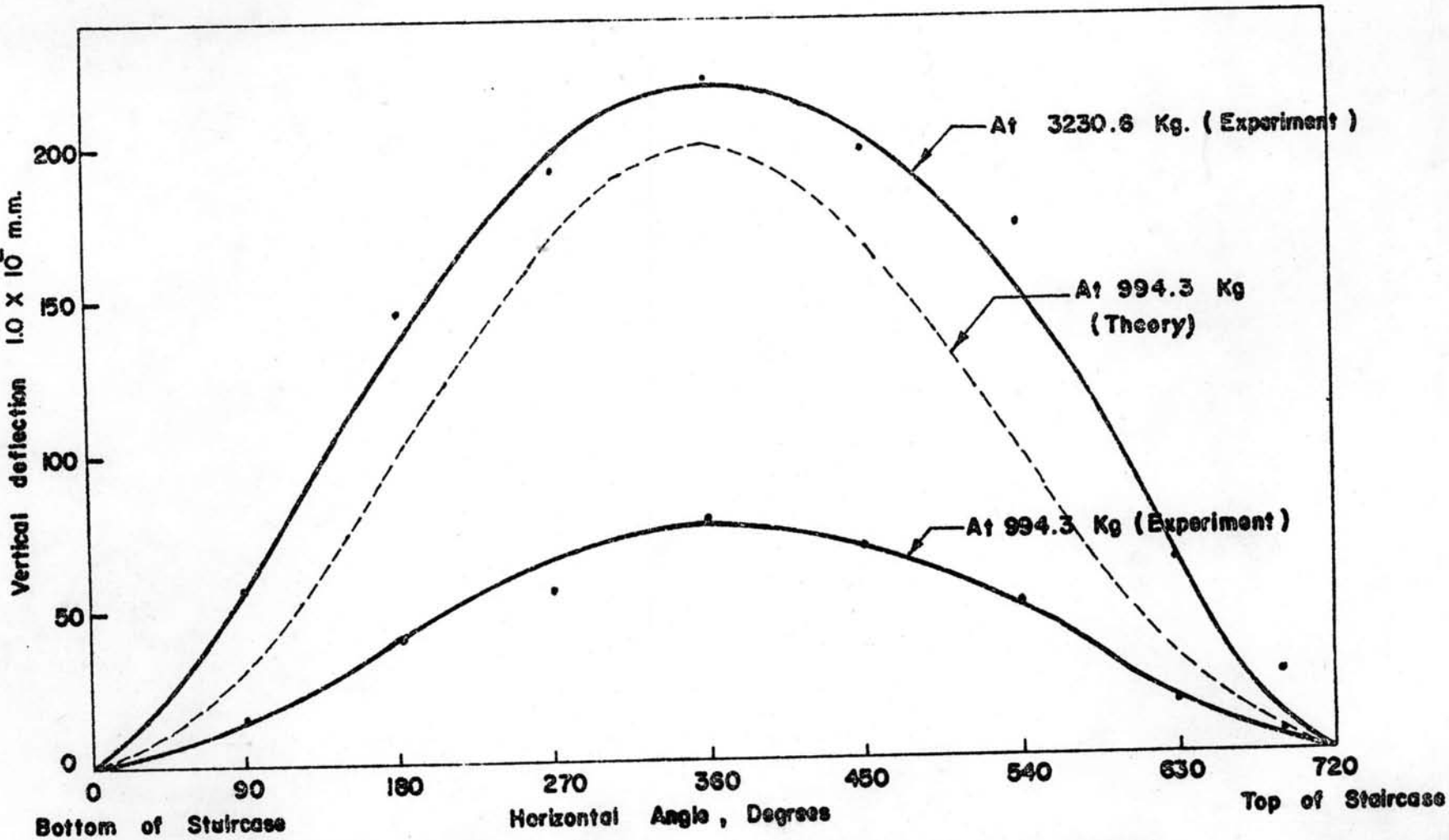


Fig 33 : Vertical deflection profile along the center line of step

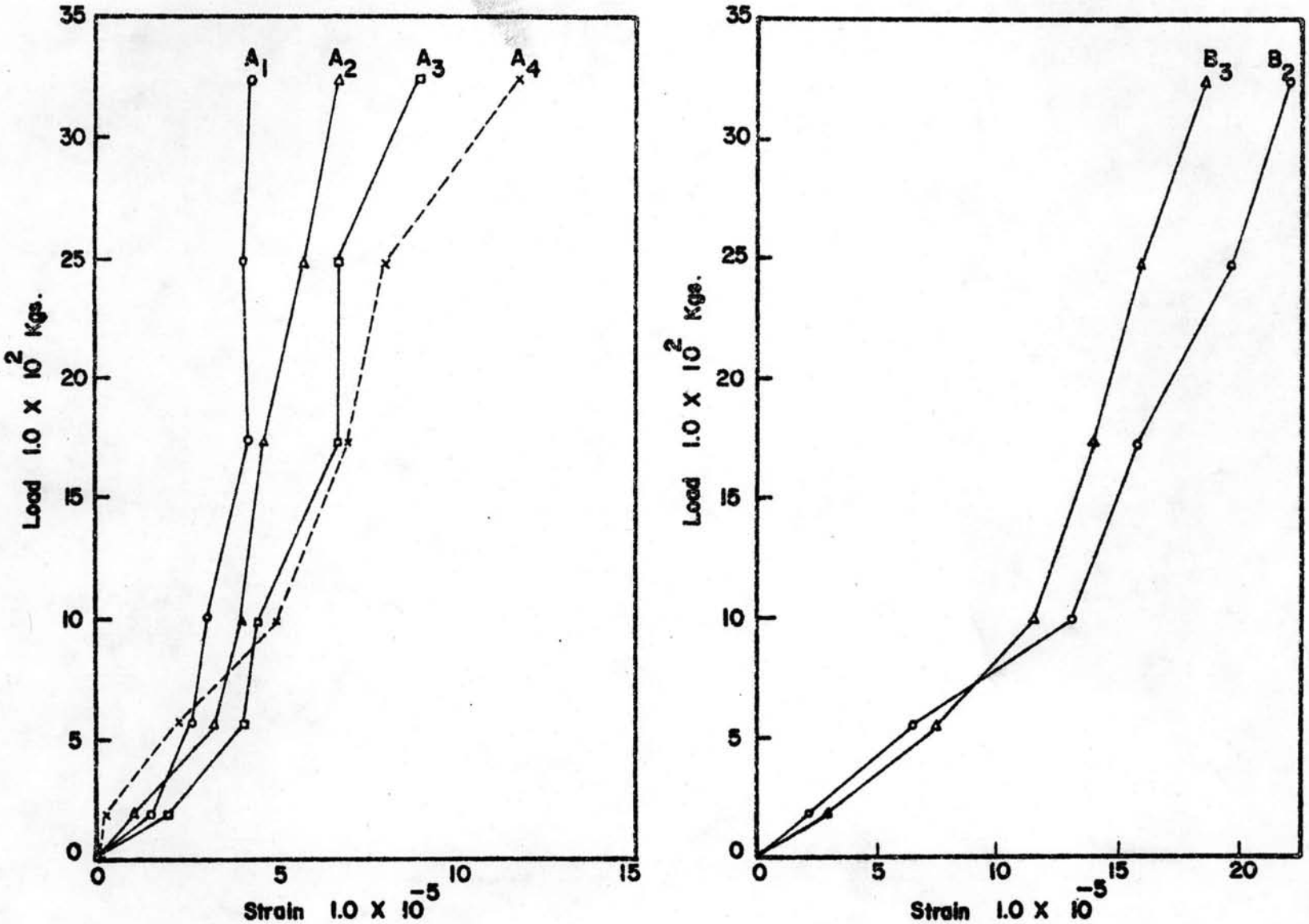


Fig 34 : Strain at station A and B

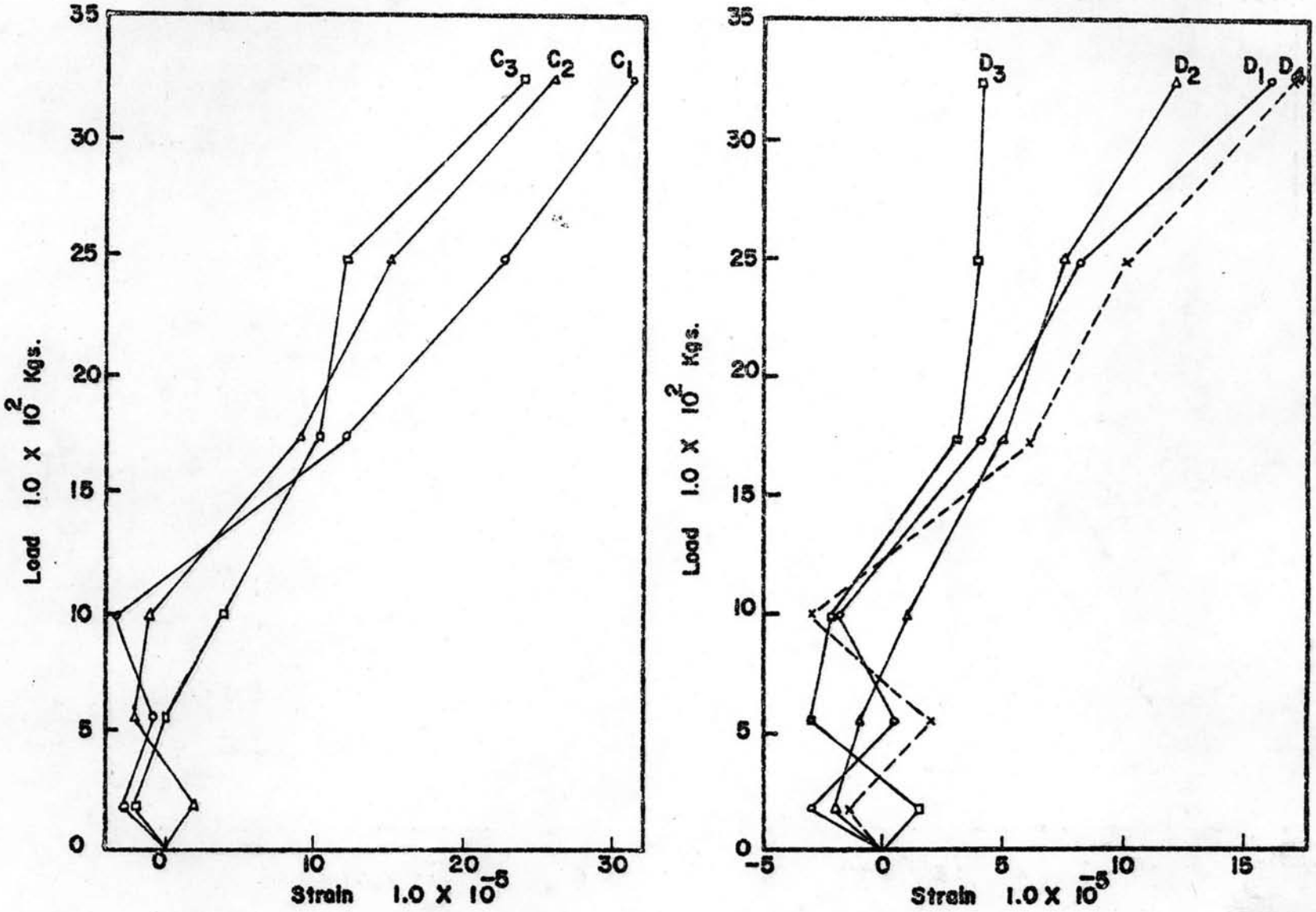


Fig 35 : Strain at station C and D

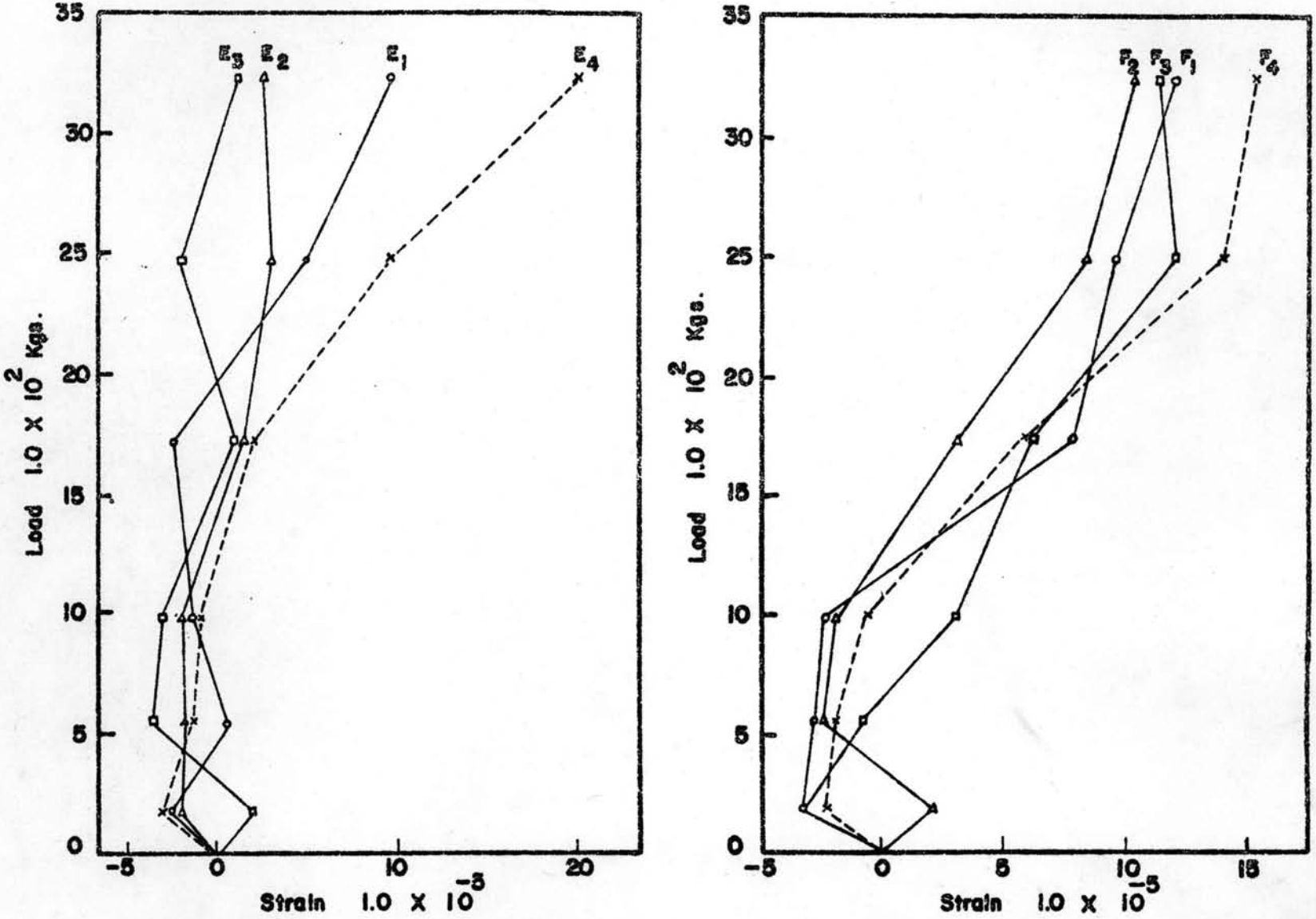


Fig 36 : Strain at station E and F

Table 15 : Comparative strain at live load 3230.6Kgs

Strain Station		Strain from direct measurement $1.0X10^{-5}$	Analytical strain* 1.0×10^{-5}
Central angle 120 degrees	A1	4.2	-3.9
	A2	6.8	-0.9
	A3	9.0	2.0
	A4	11.8	8.4
Central angle 240 degrees	B1	-	7.4
	B2	22.0	8.4
	B3	18.6	9.3
	B4	-	13.9
Central angle 360 degrees	C1	30.0	18.1
	C2	26.4	18.1
	C3	24.0	18.1
Central angle 480 degrees	D1	16.0	9.3
	D2	12.0	8.3
	D3	4.0	7.4
	D4	19.4	13.9
Central angle 600 degrees	E1	9.5	2.1
	E2	2.5	-0.9
	E3	1.0	-3.9
	E4	20.0	9.0
Central angle 690 degrees	F1	12.1	6.6
	F2	10.3	4.2
	F3	11.1	1.8
	F4	15.4	10.1

* Strain caused by live load only