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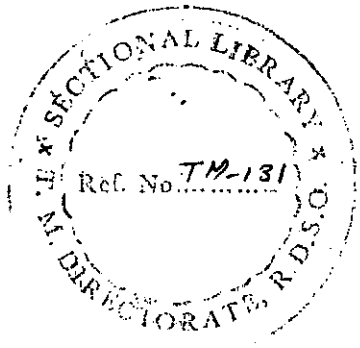

FRAME RESISTANCE OF TRACK FRAME CONSISTING OF 60KG RAIL ON 60KG PSC SLEEPERS WITH ERC MK-III

REPORT NO. - TM-131

05093

TRACK MACHINE & MONITORING DIRECTORATE

RESEARCH DESIGNS & STANDARDS ORGANISTAION
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Forward

This report is based on field trials conducted by the Track Machine & Monitoring Directorate of RDSO. Although every care has been taken in recording data accurately and in analysing it objectively, the views expressed in this report are subject to modification from time to time in the light of fresh data. Further, they do not necessarily represent the views of Ministry of Railways (Railway Board), Government of India.

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19/03/09

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FRAME RESISTANCE OF TRACK FRAME CONSISTING OF 60KG RAIL ON 60KG PSC SLEEPERS WITH ERC MK-III

1. Introduction

In order to develop the system of laying long welded rails extensively on Indian railways, it was decided to study the different parameters of long welded rails, contributing its strength against buckling of different track structures for laying long welded rails in 1976 and a technical report was published as Civil Engineering Report No. C-152.This report is based on the trials carried out on light weight track structures on 90R/60R rail sections light weight PRC sleepers, RCC sleepers, CST-9 and Steel trough sleepers with loose jaw & Key, DS-18 and Pandrol clips fastening systems.

The important parameters for buckling strength of track structure are lateral and longitudinal resistance. Lateral resistance assume much greater importance because it is the one, which contributes to its strength against buckling. The buckling tendency is created by the compressive force under high temperature, when the condition in central part is similar to that of a long column under load. The two factors which provides the lateral resistance, are (i) lateral rigidity of track frame (ii) lateral ballast resistance .

The lateral rigidity is corresponding to EI in the Euler Equation of column;

$$P = \pi^2 EI/L^2$$

Track undergoing lateral distortion acts as a veirendeel girder with not too rigid joints. Since, the connection between rails and sleepers is not rigid, EI can not be taken as for two rails placed gauge distance apart. It depends on torsional resistance of rail sleepers fastening. It is, therefore, called EI equivalent and is known to depend on type and spacing of sleepers, types of fastening, distorted length and extent of distortion. It has therefore, to be determined experimentaliy by making a track panel, putting it on rollers and observing the load and deflection pattern. EI equivalent has to be determined by applying the simply supported beam formula of deflection;

$$Def = WL^3/48EI$$

This report deals with the lateral rigidity of track frame with 60 kg rails and 60Kg PSC sleepers (Drg. no. RDSO/T-2496) with ERC MK-III fastenings(Drg.

no. RDSO/T-3701) for different sleepers spacings which are being used all over Indian railways at present.

The study of lateral stability of LWR under longitudinal load due to thermal forces can be divided in to two parts (i) the resistance offered by the track frame consisting of rails, sleepers and fastening, (ii) the resistance offered by the ballast to lateral movement of sleepers. The former is called frame resistance and latter is called ballast resistance. The frame resistance which is the lateral stiffness of the track frame, depends upon type of rails, sleepers, sleepers fastening, length of distortion and lateral deflection.

Track Design Dte. formulated a trial scheme for determination of Frame resistance Value for 60/52Kg rails and 60Kg PSC sleepers with sleeper density of 1540,1660 & 1818 nos./Km.

2. Test Track

2.1 Track

All the trials were conducted on track frame prepared near EMS workshop/RDSO. Track frame for one rail length track was prepared (detailed drg. enclosed as Fig. 2) . This frame was placed on level ground supported on rollers to minimise friction. The frame was laterally supported on two supports to give the required span. The details of track structure during different trials are as under:

(i) 60 Kg new rails, 60 Kg PSC sleeper @ 1540/Km (sleeper spacing-65cm) with elastic rail clips (ERC MK-III) and grooved rubber sole plate (GRSP).

(ii) 60 Kg new rails, 60 Kg PSC sleeper @ 1660/Km (sleeper spacing-60cm) with elastic rail clips (ERC MK-III) and grooved rubber sole plate (GRSP).

(iii) 60 Kg new rails, 60 Kg PSC sleeper @ 1818/Km (sleeper spacing-55cm) with elastic rail clips (ERC MK-III) and grooved rubber sole plate (GRSP).

The trial were repeated for 5, 6, 7 and 8 mt. spans of reaction supports for above mentioned track structure(i to iii). The trials were also carried out for missing ERCs on alternate sleeper pattern as per fig. 1 (b).

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2.2 **Application of load**

Hydraulic jack of 20T capacity was used for applying load laterally. Proving ring of capacity 6000Kg was used for recording applied load and corresponding deflections were measured with deflection dial gauges fixed with both rails (i.e. LR- loading rail & OR- other rail). Load was then applied centrally on the opposite side and gradually increased till max deflection of 50 mm on dial gauges or maximum stress of 46Kg/mm^2 in foot of rail (whichever is earlier) is achieved. The initial deflection has been recorded at 200 kg of load. Each test was carried out for application of load for getting deflection up to about 50mm since stress in the rail foot remained below 46 kg/mm^2 in all cases.

2.3 **Instrumentation of Rails :**

Strain gauges (10mm size-120 ohms) were fixed at mid length of the rail (i.e. 6.5 mt. from one end of the rail) on foot of the rail, where maximum stresses developed and electronic circuits were prepared to observe the stress at foot of the rail. The Kyowa, Japan make strain gauges were fixed on rail, which have the following characteristics.

. Type: KFG-10-120-C1-11

. Gauge length: 10mm

. Gauge resistance: 119.8±0.2 ohms

. Gauge factor (24 °C,50%RH): 2.11±1.0%

. Adoptable thermal expansion: 11.7ppm/°c

. Transverse sensitivity (24 °C, 50%RH):0.20%

. Temperature coefficient of gauge factor: 0.8±0.5%/100 deg

. Tolerance: 0.85μ m/m per° C

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3. Measurement and Recording instruments:

The measurement of load, corresponding deflection and stress in the foot of rail were recorded with the help of proving ring, deflection dial gauge and Astromed recorder.

4. Calibration :

4.1 Calibration of proving ring:

20t hydraulic jacks were used for load application. These jacks were calibrated and applied load was recorded by using proving ring capacity 10000kg available in TM Dte.. This proving ring was calibrated on dated 22-07-2009 at Regional Testing Canter (NR), Ministry of SSI, New Delhi with validity upto 18-2-2009.

4.2 Calibration of Data acquisition System for Recording the Stress:

The Astromed recorder used for recording the stress was calibrated every day before acquiring the data as per the procedure given below.

1. The strain gauge fixed at the foot of the rail forms one arm of wheat stone bridge and dummy strain gauges are provided in other three arms of the bridge.
2. The wheat stone bridge is balanced.
3. A known shunt resistance is provided in parallel to the active strain gauge.
4. With the help of the gauge factor of the strain gauge, the gauge is calibrated to directly record the stress in the rail as explained below:

Let 'Rg' be the strain gauge resistance, Rsh the shunt resistance and Rg' the equivalent resistance.

Let $\Delta R = Rg - Rg'$ (By definition of GF)

Gauge factor $GF = (\Delta R/Rg)/Strain$

$1/Rg' = 1/Rg + 1/Rsh$

$Rg' = Rg \times Rsh / (Rg+Rsh)$

$\Delta R = Rg - Rg' = Rg - Rg \times Rsh /(Rg+Rsh)$

$=(Rg)^2/(Rg+Rsh)$

Or $\Delta R/Rg = Rg/(Rg+Rsh) = GF \times Strain$

$Strain = Rg/GF\ (Rg+Rsh)$ ----------Equation-1

$Stress = Rg \times E/GF(Rg+Rsh)$ ----------Equation-2

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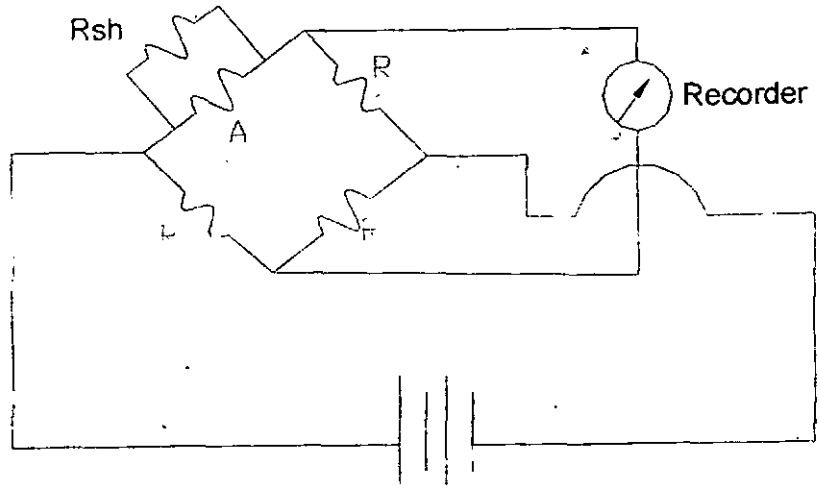
E ⇒ known

GF ⇒ Given by manufacture of strain gauge

Rsh ⇒ known shunt resistence

Rg ⇒ Variable



A - Active strain gauge
R – Dummy strain gauge
Rsh – Shunt Resistance

5.Test Schedule:

Field trial were carried out in February-March,2009 on the track frame mentioned in para 2.1 with full ERC fittings and missing ERC's on alternate sleeper pattern.

6. Material/Equipment used :

1. Rail 60Kg(90UTS)
2. PSC Sleeper 60Kg (Drg. No. RDSO/T- 2496)
3. GRSP (RDSO/T-3711)
4. GFN liner (Drg. no. RDSO/T-3706)
5. ERC Mk-III (RDSO/T-3701)
6. Hydraulic Jack 20T capacity
7. Proving Ring 10000Kg capacity
8. Dial Gauges (50 mm deflection , least count-0.01mm), Mitutoyo make
9. Astromed recorder
10. Strain gauges 10mm size, 120 Ω resistance

7. Method of Analysis: Average deflection of both rails has been taken for calculation of Eleq value. The Eleq (EI equivalent) for the frame is calculated for the average deflection and load by using the simple beam formula:

$$\text{Def. 'D'} = \frac{W \times L^3}{48 \times EI}$$

where 'W' is applied load for deflection 'D'.

L is span between reaction supports.

The recorded load, deflections and calculated Eleq are tabulated for different sleeper spacings and span of supports in table 1 to table 24.

The graph (best fit curve) is plotted for the recorded values of load Vs deflection and the best fit curve drawn for the values of deflection Vs Eleq.

From these curves, it can be seen that Eleq values are decreasing with increase in deflection and become asymptotic for larger deflection attenning at minimum value.

8. Summary : Details of load, measured deflections and calculated Eleq for different sleeper spacing, spans and pattern of ERC are presented in tabular form in table 1 to 24 . The graphs derived on basis of load, measured deflections and calculated Eleq is annexed as graph 1 to 24 .Graph no. I,II,III,IV shows the comparison of load Vs Eleq on different spans on sleeper spacings with full ERC pattern and missing ERCs on alternate sleeper pattern.

9. Observations : The data observed and analysed for Eleq for different sleeper spacing are given in Table A and B .

1 : Effect of deflection :- It can be seen from Table A that with increase in deflection Eleq decreases .

2 : Effect of span of supports :- It is also observed that with increase in span (length of distorted track), Eleq value increases. Eleq value is highest for 8 mt. span.

3 : Effect of sleeper spacing :- As evident from table A & B, Eleq value decreases if the sleeper spacing increases. Eleq value is highest in case of sleeper spacing of 55 cm.

4 : Effect of pattern of ERC fastening :- Track with complete ERCs shows a higher Eleq value in comparison to the loose ERCs pattern as per Table A and B.

10. Errors Due to Friction :- i) The surface where track frame placed on rollers was not levelled accurately and smooth. Therefore, some friction occurred between rollers and surface.

ii) To minimise friction between rollers and sleepers, a steel piate was placed between rollers and sleepers.

Table A: (Track Frame with full ERC)

Sleeper spacing	Span (met)	Load (kg)		Avg Def (mm)		Eléq (t/m²)	
		Min	Max	Min	Max	Max	Min
55 cm	5	200	5800	1.09	46.38	480	322
	8	200	2400	2.61	45.95	817	557
60 cm	5	200	5600	1.21	47.20	430	309
	8	200	2000	2.90	48.90	736	436
65 cm	5	200	5000	1.33	44.41	392	293
	8	200	1800	3.26	49.15	654	391

Table B: (Track frame with missing ERCs on alternate sleeper)

Sleeper spacing	Span (met)	Load (kg)		Avg Def (mm)		Eleq (t/m²)	
		Min	Max	Min	Max	Max	Min
55 cm	5	200	5000	1.27	47.23	412	276
	8	200	2000	3.05	46.7	699	457
60 cm	5	200	4800	1.37	47.05	380	266
	8	200	1800	3.29	48.05	648	400
65 cm	5	200	4600	1.48	46.65	352	257
	8	200	1500	4.04	48.38	529	331

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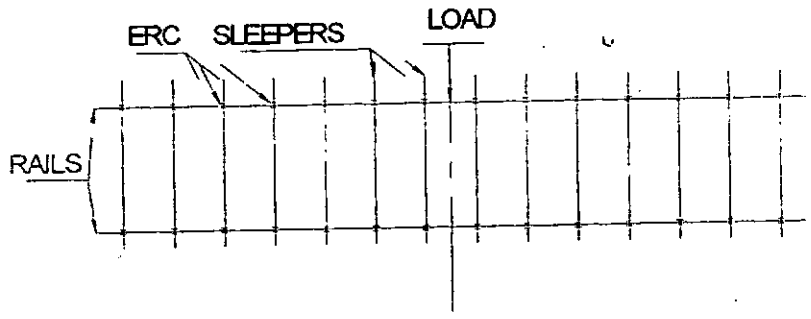


FIG. 1(a) : TRACK FRAME WITH FULL ERC

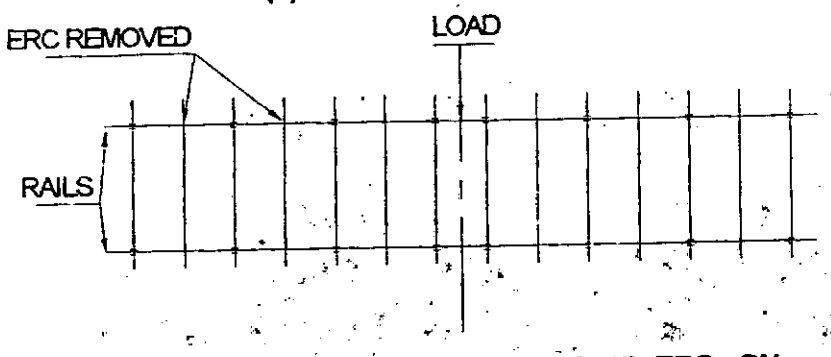
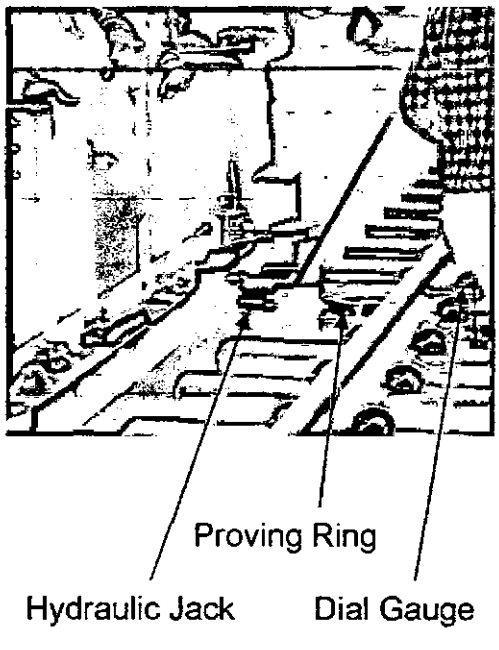


FIG. 1(b): TRACK FRAME WITH MISSING ERCs ON ALTERNATE SLEEPER



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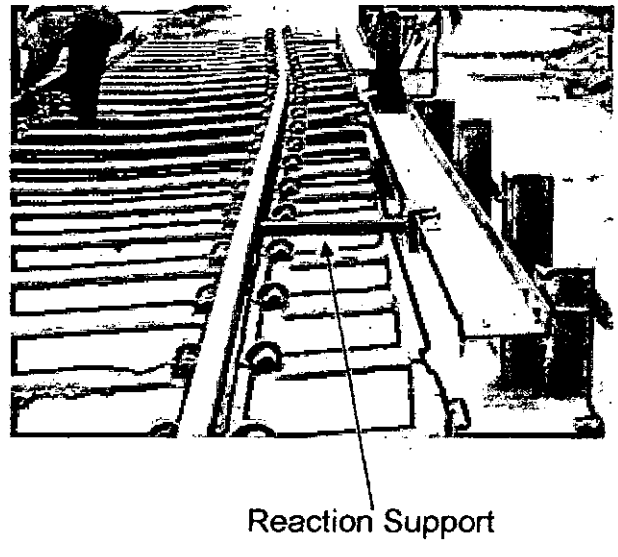
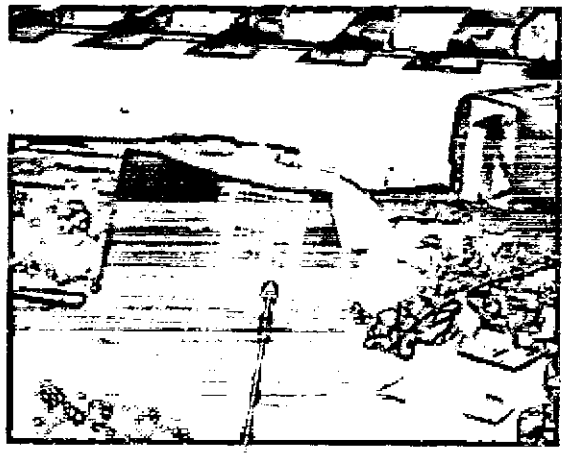


Photo:2

Photographs showing Track Frame assembly and loading set up



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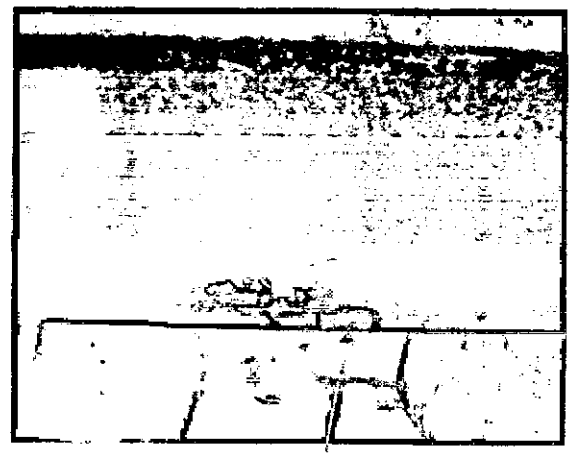

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Photographs showing position of Strain Gauges on rail and Data Acquisition System

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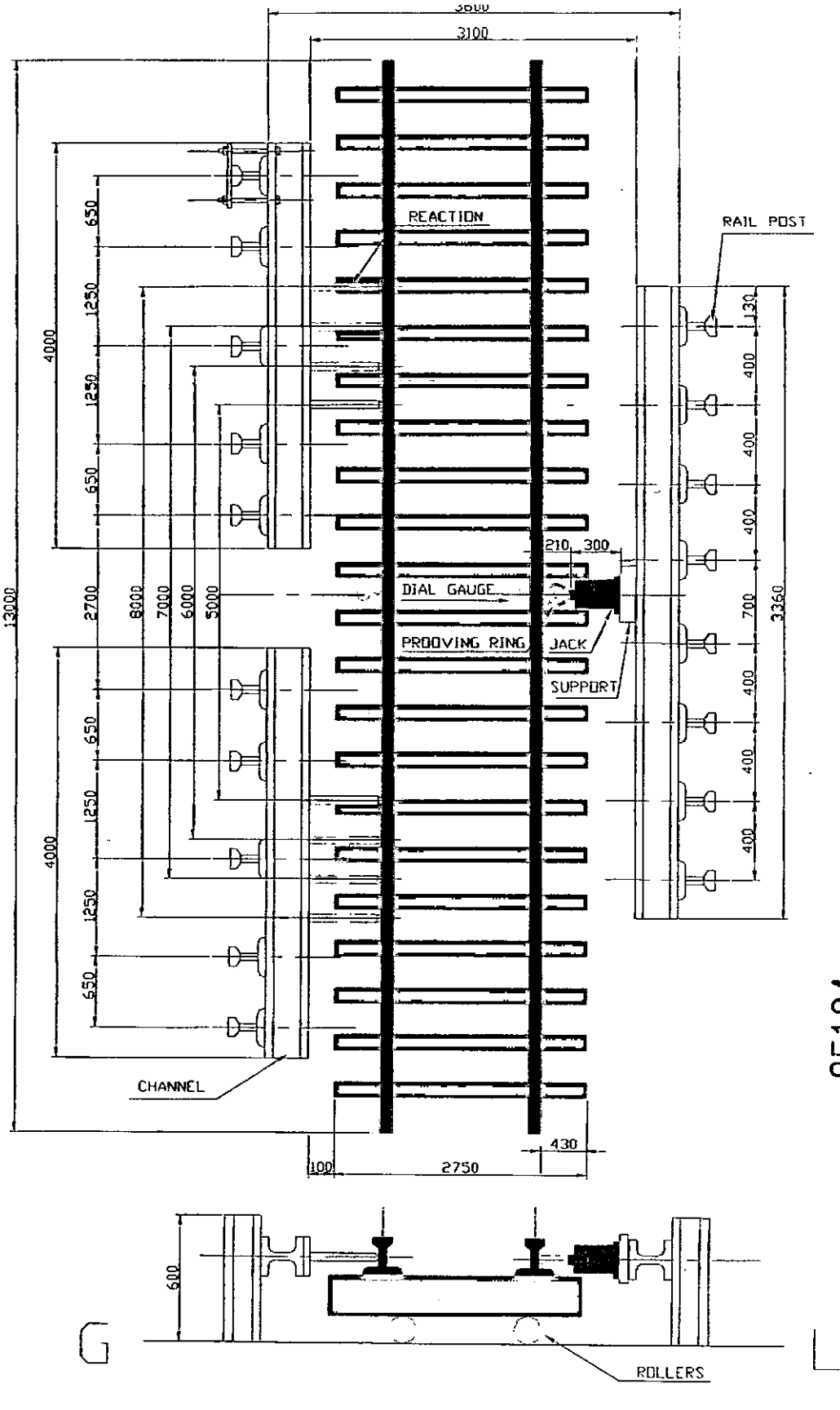
FIG. 2



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TEST SETUP PLAN FOR FRAME RESISTANCE TRIALS

$$E = 2.11 \times 10^6 \text{ kg/cm}^2$$

$$= 2.11 \times 10^6 \times \frac{10^4}{10^3} \text{ t/m}^2$$

$$= 2.11 \times 10^7 \text{ t/m}^2$$

$$I = 512.9 \text{ cm}^4 = 512.9 \times 10^{-8} \text{ m}^4$$

$$EI = 2.11 \times 10^7 \times 512.9 \times 10^{-8}$$

$$= 108.22 \text{ t/m}^2$$

$$\boxed{2EI = 2 \times 108.22 = 216.44 \text{ t/m}^2}$$

This report is based on the investigations conducted by a team consisting of following officers and staff under guidance of Sri Anil Kumar Jt. Director/ TM-I

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8.	Sri R.P.S. Payal	-	TG-I
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10.	Sri Nankoo	-	TG-I
11.	Sri B.S. Chauhan	-	TG-II
12.	Sri P.N. Mishra	-	TG-III

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Table C : Summry ، load, measured deflection and c culated Eleq. For 60 kg rail

Sleeper Spacing	Span in met	Full ERC						Missing ERC					
		Load (kg)		Avg Def (mm)		Eleq (t/sq m)		Load (kg)		Avg Def (mm)		Eleq (t/sq m)	
		Min	Max	Min	Max	Max	Min	Min	Max	Min	Max	Max	Min
55 cm	5	200	5800	1.09	46.98	480	322	200	5000	1.27	47.23	412	276
	6	200	4000	1.71	48.33	526	372	200	3400	1.87	47.70	481	321
	7	200	2800	2.03	45.30	704	442	200	2400	2.29	44.60	624	385
	8	200	2400	2.61	45.95	817	557	200	2000	3.05	46.70	699	457
60 cm	5	200	5600	1.21	47.20	430	309	200	4800	1.37	47.05	380	266
	6	200	3800	1.77	49.38	508	346	200	3000	2.12	46.31	425	292
	7	200	2600	2.44	49.48	587	376	200	2400	2.59	49.48	552	347
	8	200	2000	2.90	48.90	736	436	200	1800	3.29	48.05	648	400
65 cm	5	200	5000	1.33	44.41	392	293	200	4600	1.48	46.65	352	257
	6	200	3200	1.86	45.60	485	316	200	2800	2.20	44.98	409	280
	7	200	2400	2.75	46.90	520	366	200	2100	3.01	48.10	475	312
	8	200	1800	3.26	49.15	654	391	200	1500	4.04	48.38	529	331

* Proving ring of capacity 10000 kg has been used for trial.

* The initial deflection has been taken at 200 kg of lateral load.

* The deflection given in table is the average value of deflection recorded by two dial gauges. It is obs erved that in all cases, dial gauge provided on rail on which load was applied, attained the limiting value of 50 mm.

* **By this trail it is clear that the frame rigidity (Eleq value) decreases with decrease in sleeper density or increase sleeper spacing.**

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Spacing - 55cm
Span - 5m
Pattern - Full ERC

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def mm)	EI (t/sq m)
1	200	1.09	1.08	1.09	480
2	400	2.25	2.15	2.20	473
3	600	3.47	3.26	3.37	464
4	800	4.70	4.40	4.55	458
5	1000	6.02	5.62	5.82	447
6	1200	7.25	6.79	7.02	445
7	1400	8.52	8.02	8.27	441
8	1600	9.90	9.35	9.63	433
9	1800	11.35	10.50	10.93	429
10	2000	12.85	11.90	12.38	421
11	2200	14.25	13.20	13.73	417
12	2400	15.80	14.75	15.28	409
13	2600	17.40	16.25	16.83	402
14	2800	19.20	17.95	18.58	393
15	3000	20.82	19.41	20.12	388
16	3200	22.65	21.10	21.88	381
17	3400	24.55	23.01	23.78	372
18	3600	26.05	24.45	25.25	371
19	3800	27.55	25.95	26.75	370
20	4000	29.42	27.70	28.56	365
21	4200	31.60	29.40	30.50	359
22	4400	33.72	31.80	32.76	350
23	4600	35.82	33.70	34.76	345
24	4800	37.91	35.90	36.91	339
25	5000	39.55	37.50	38.53	338
26	5200	41.45	39.30	40.38	335
27	5400	43.70	41.60	42.65	330
28	5600	45.55	43.40	44.48	328
29	**5800**	**48.10**	**45.85**	**46.98**	**322**

Table 1 : Showing Load, measured deflections and calculated EI

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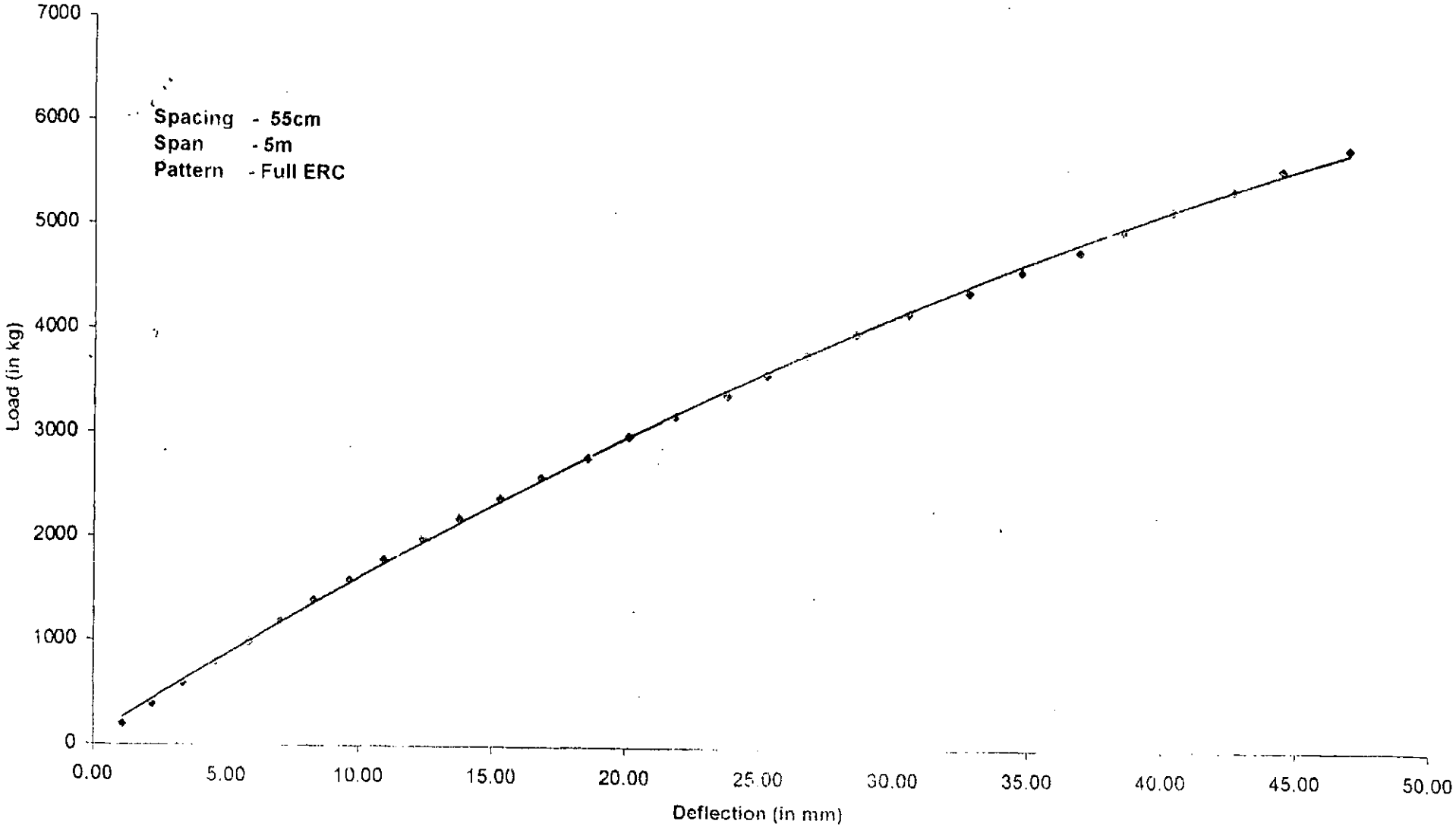

Graph 1A :Load Vs Deflection

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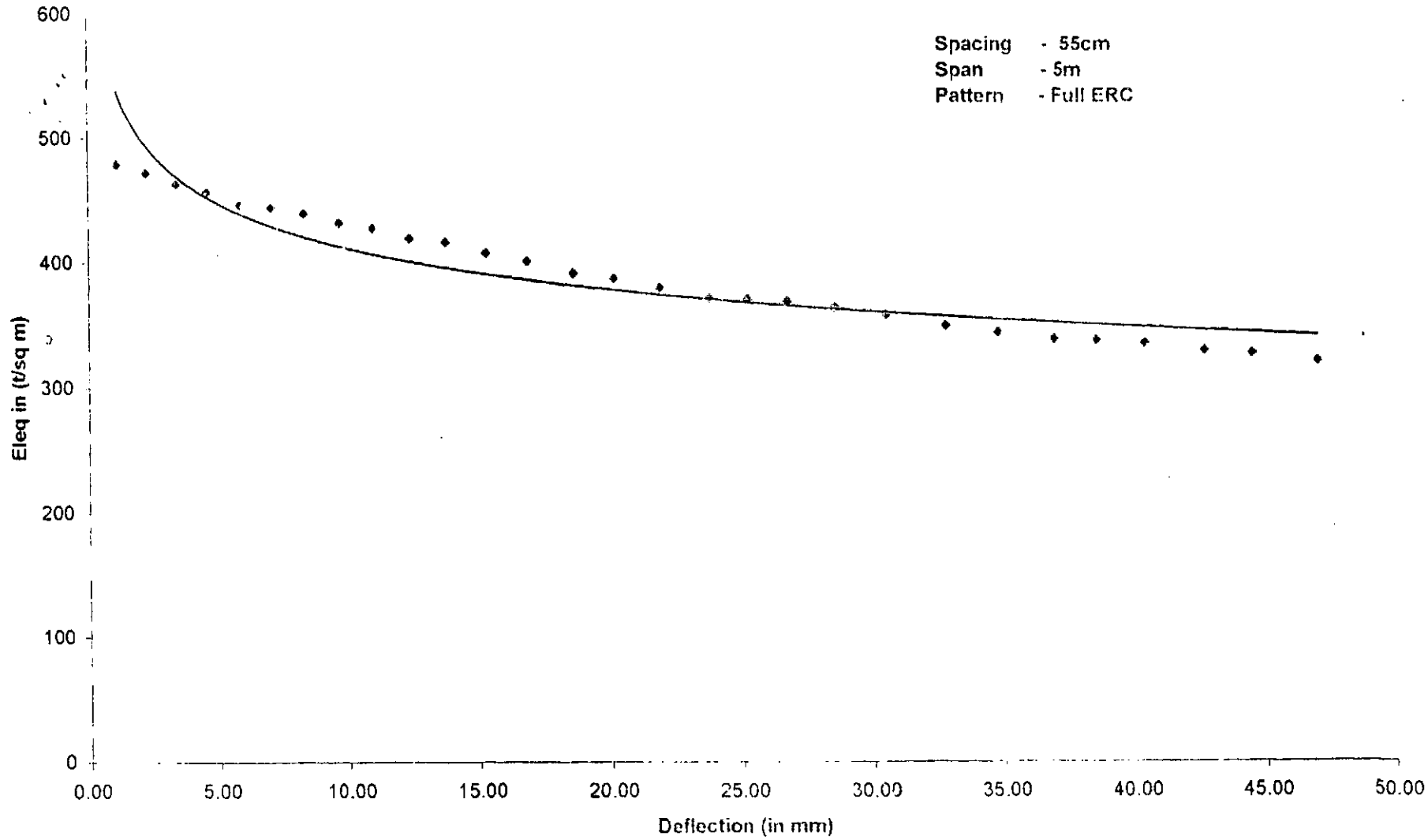

Graph 1B : Deflection Vs Eleq

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Spacing - 55cm
Span - 6m
Pattern - Full ERC

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def mm)	EI (t/sq m)
1	200	1.72	1.70	1.71	526
2	400	3.52	3.45	3.49	516
3	600	5.50	5.32	5.41	499
4	800	7.52	7.18	7.35	490
5	1000	9.51	8.95	9.23	488
6	1200	11.55	10.65	11.10	486
7	1400	13.70	12.62	13.16	479
8	1600	15.65	14.52	15.09	477
9	1800	17.85	16.50	17.18	472
10	2000	20.05	18.85	19.45	463
11	2200	22.55	21.30	21.93	452
12	2400	25.40	23.85	24.63	439
13	2600	28.35	26.65	27.50	425
14	2800	31.30	29.80	30.55	412
15	3000	34.32	32.80	33.56	402
16	3200	37.45	35.75	36.60	393
17	3400	40.48	38.70	39.59	386
18	3600	43.50	41.45	42.48	381
19	3800	46.52	44.45	45.49	376
20	4000	49.45	47.20	48.33	372

Table 2 : Showing Load, measured deflections and calculated EI

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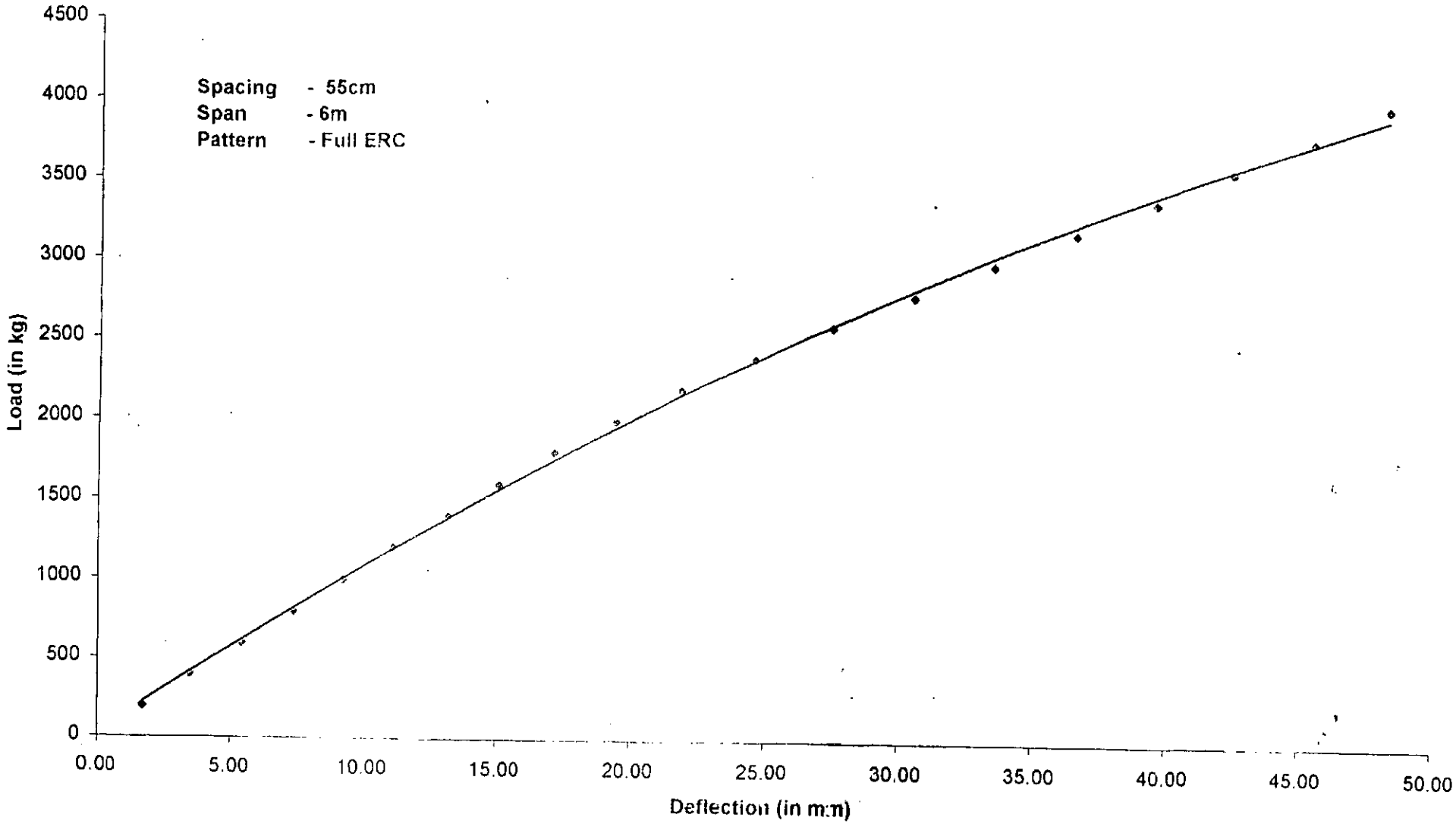

Graph 2A : Load Vs Deflection

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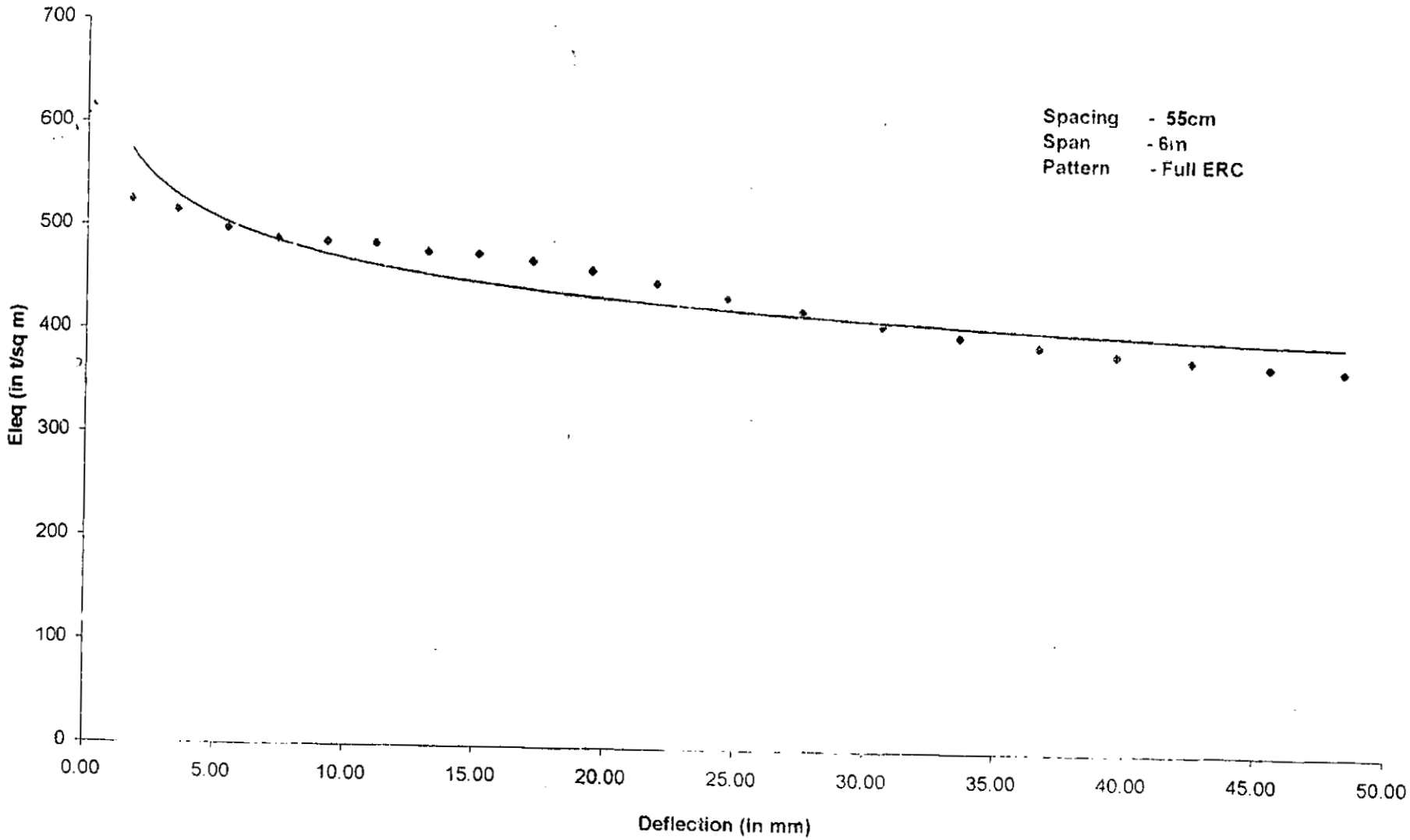

Graph 2B :Deflection Vs Eleq

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Spacing - 55cm
Span - 7m
Pattern - Full ERC

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	EI (t/sq m)
1	200	2.04	2.02	2.03	704
2	400	4.16	4.05	4.11	696
3	600	6.52	6.35	6.44	666
4	800	9.17	8.90	9.04	633
5	1000	11.90	11.50	11.70	611
6	1200	14.89	14.21	14.55	589
7	1400	18.12	17.30	17.71	565
8	1600	21.20	20.45	20.83	549
9	1800	24.70	23.80	24.25	530
10	2000	28.32	27.25	27.79	514
11	2200	32.80	31.62	32.21	488
12	2400	36.82	35.30	36.06	476
13	2600	41.50	39.78	40.64	457
14	**2800**	**46.35**	**44.30**	**45.33**	**441**

Table 3 : Showing Load, measured deflections and calculated EI

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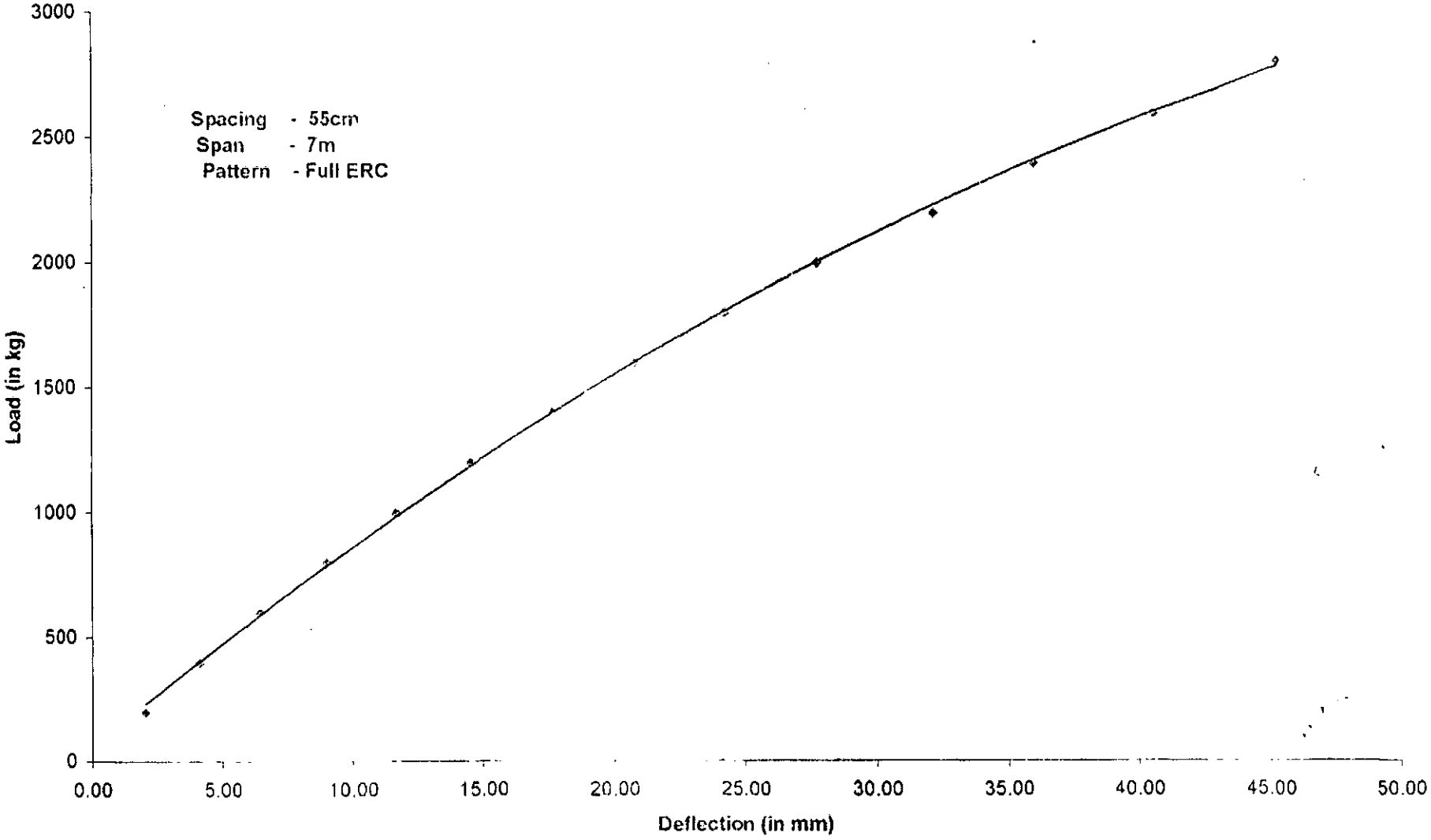
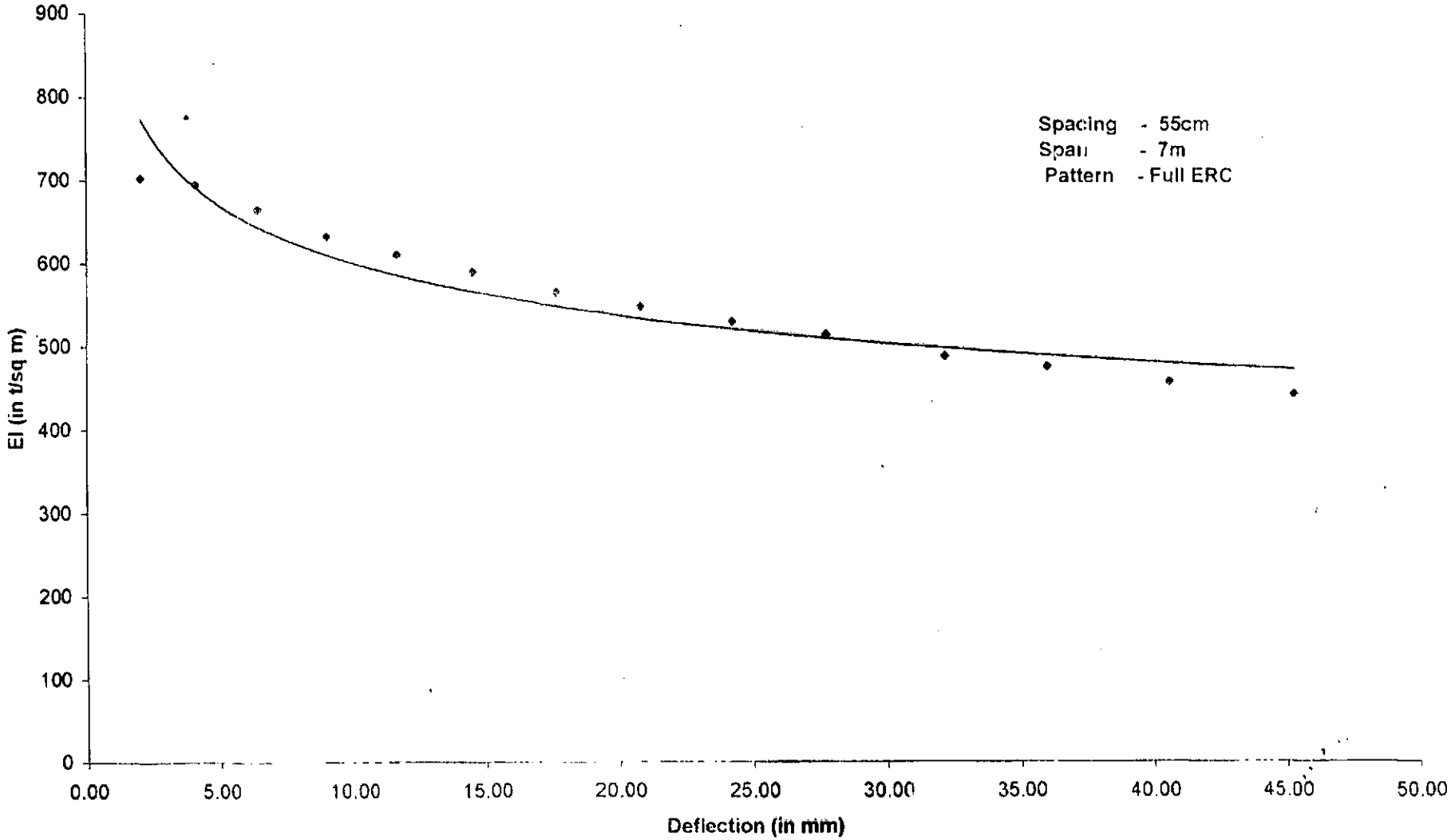


Graph 3A : Load Vs Deflection

05114



Graph 3B : Deflection Vs Eleq

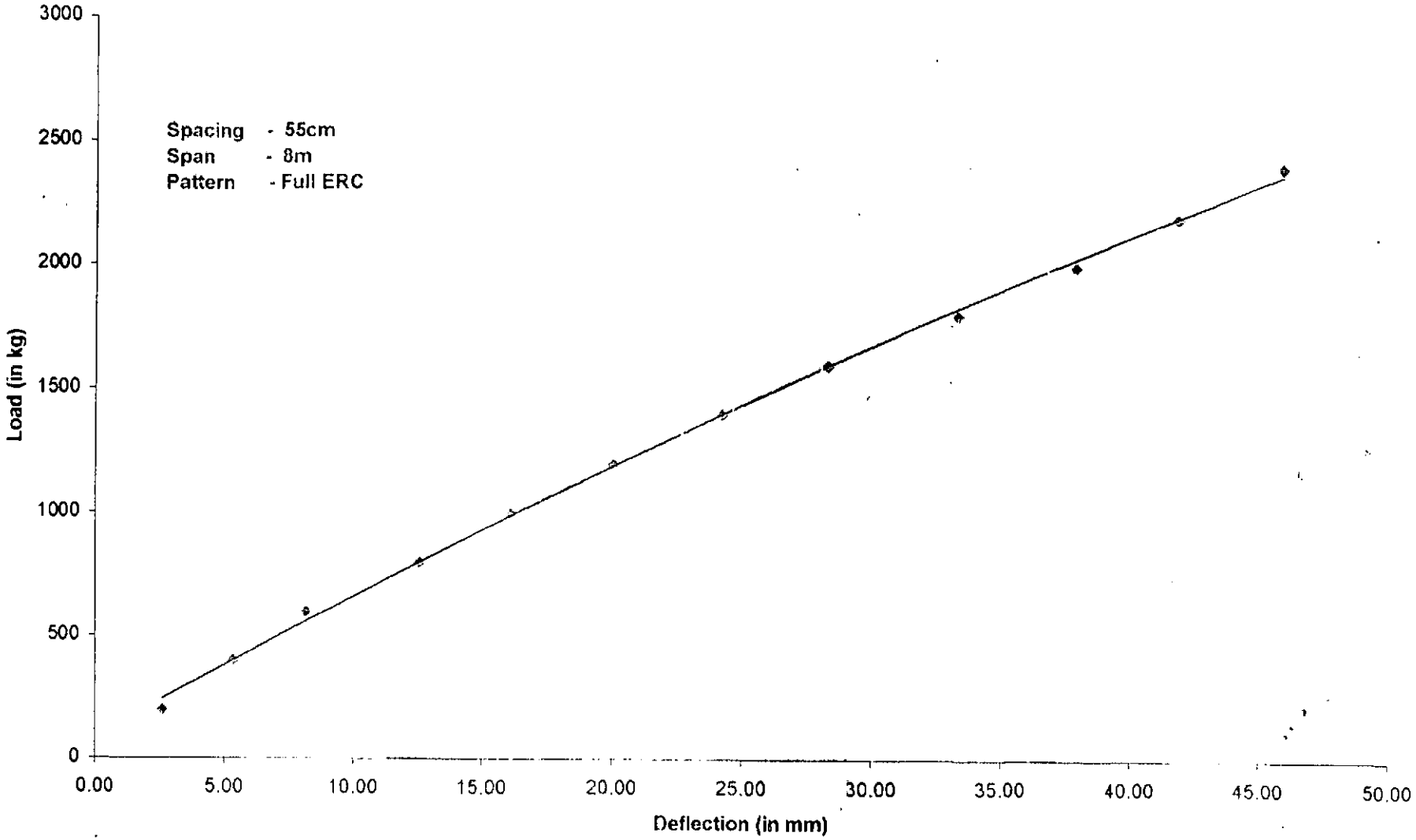
05115

Spacing - 55cm
Span - 8m
Pattern - Full ERC

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	EI (t/sq m)
1	200	2.62	2.60	2.61	817
2	400	5.40	5.25	5.33	801
3	600	8.40	7.95	8.18	783
4	800	12.99	12.20	12.60	678
5	1000	16.50	15.70	16.10	663
6	1200	20.60	19.50	20.05	638
7	1400	24.85	23.65	24.25	616
8	1600	29.10	27.60	28.35	602
9	1800	34.25	32.50	33.38	575
10	2000	38.95	36.85	37.9	563
11	2200	42.95	40.80	41.88	560
12	**2400**	**47.05**	**44.85**	**45.95**	**557**

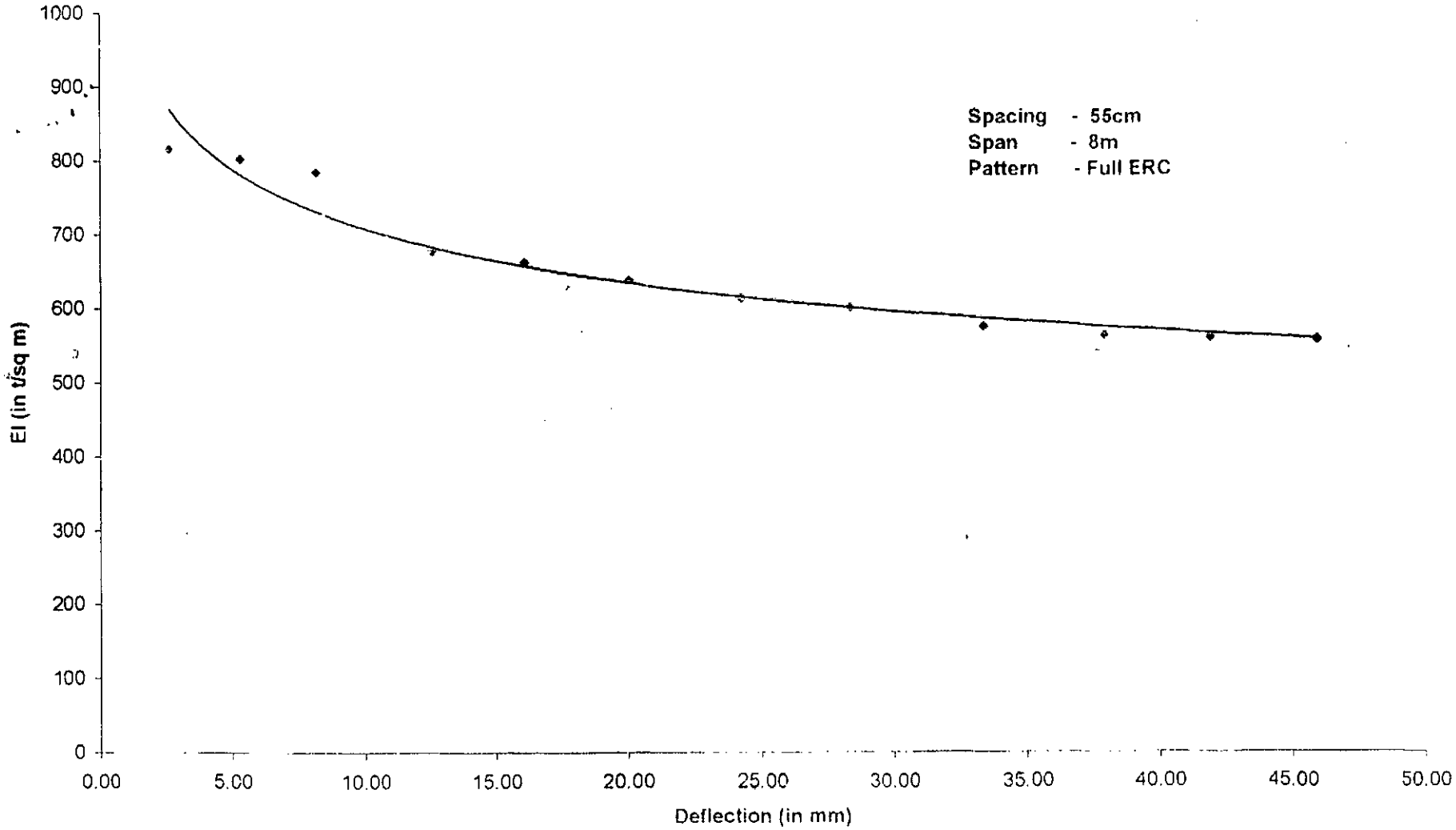
Table 4 : Showing Load, measured deflections and calculated EI

05116



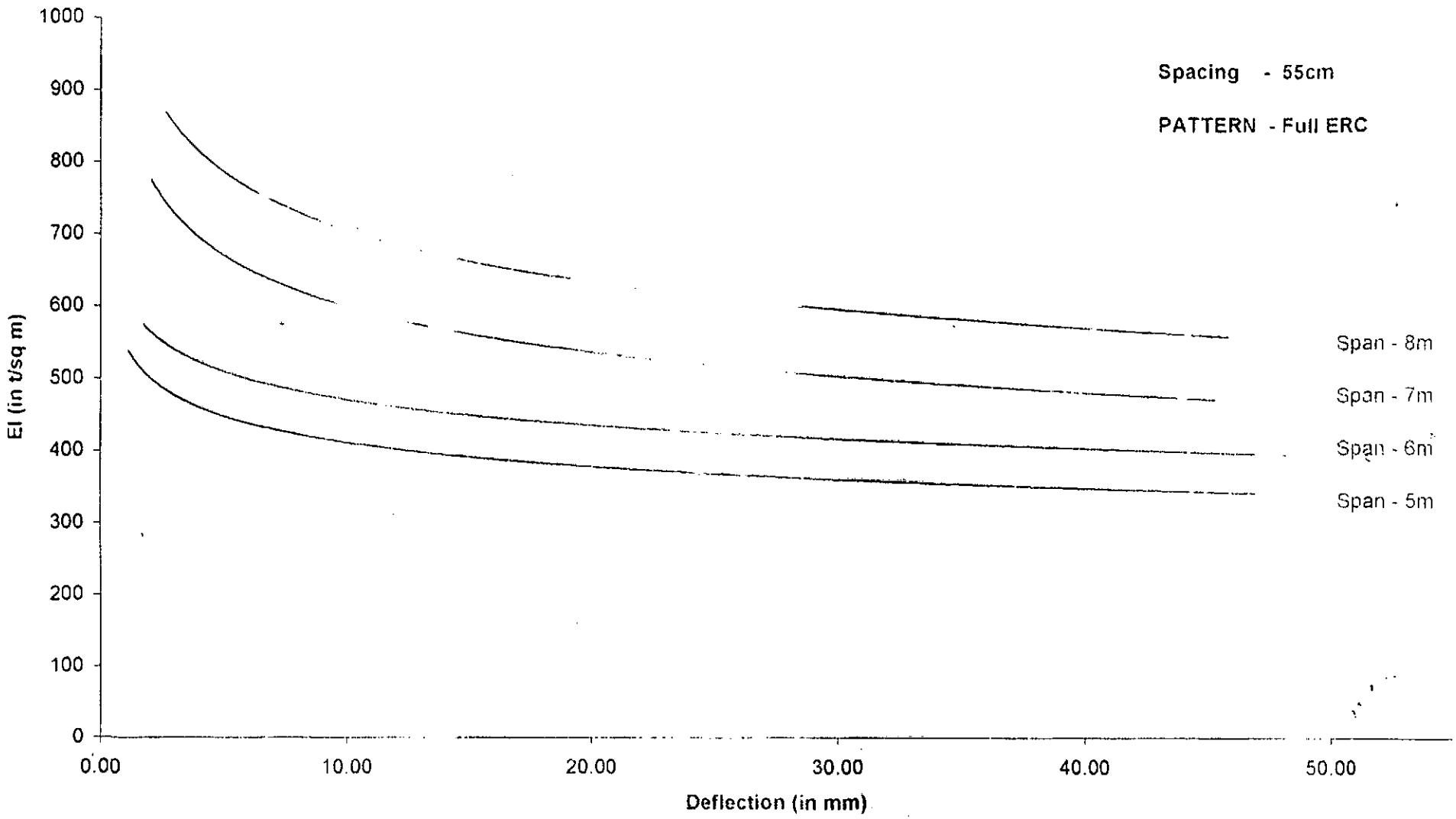
Graph 4A : Load Vs Deflection

05117



Graph 4B : Deflection Vs Eleq

05118



Graph : Combined Deflection Vs EI

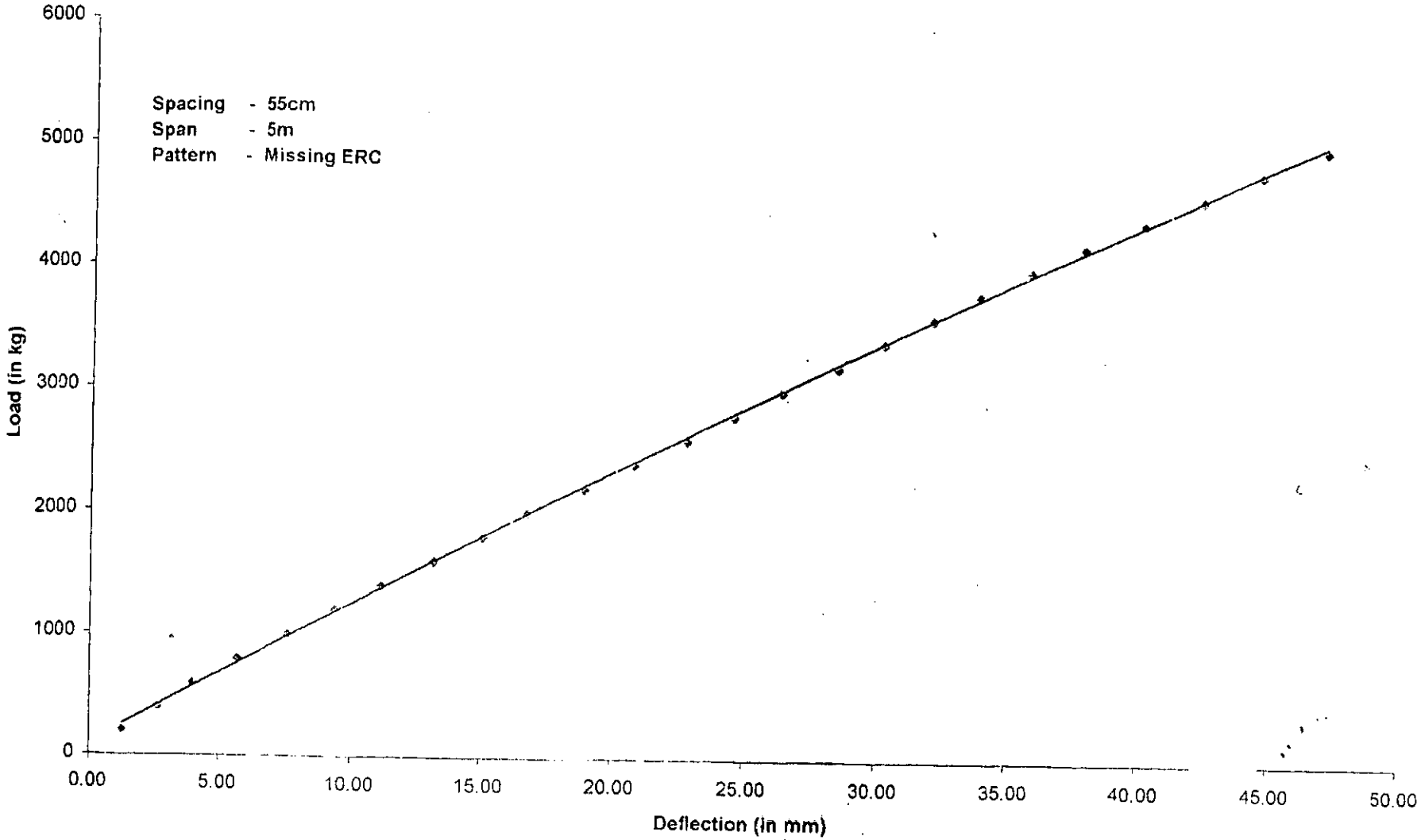
05119

Spacing - 55cm
Span - 5m
Pattern - Missing ERC

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	1.28	1.25	1.27	412
2	400	2.66	2.58	2.62	398
3	600	4.12	3.90	4.01	390
4	800	5.85	5.55	5.70	365
5	1000	7.85	7.41	7.63	341
6	1200	9.68	9.13	9.41	332
7	1400	11.54	10.85	11.20	326
8	1600	13.62	12.83	13.23	315
9	1800	15.55	14.60	15.08	311
10	2000	17.30	16.24	16.77	311
11	2200	19.56	18.35	18.96	302
12	2400	21.00	20.65	20.83	300
13	2600	23.20	22.50	22.85	296
14	2800	24.96	24.28	24.62	296
15	3000	26.84	25.99	26.42	296
16	3200	28.96	28.15	28.56	292
17	3400	30.78	29.85	30.32	292
18	3600	32.70	31.65	32.18	291
19	3800	34.56	33.40	33.98	291
20	4000	36.05	35.83	35.94	290
21	4200	38.65	37.30	37.98	288
22	4400	40.98	39.50	40.24	285
23	4600	43.25	41.70	42.48	282
24	4800	45.60	43.90	44.75	279
25	**5000**	**48.25**	**46.20**	**47.23**	276

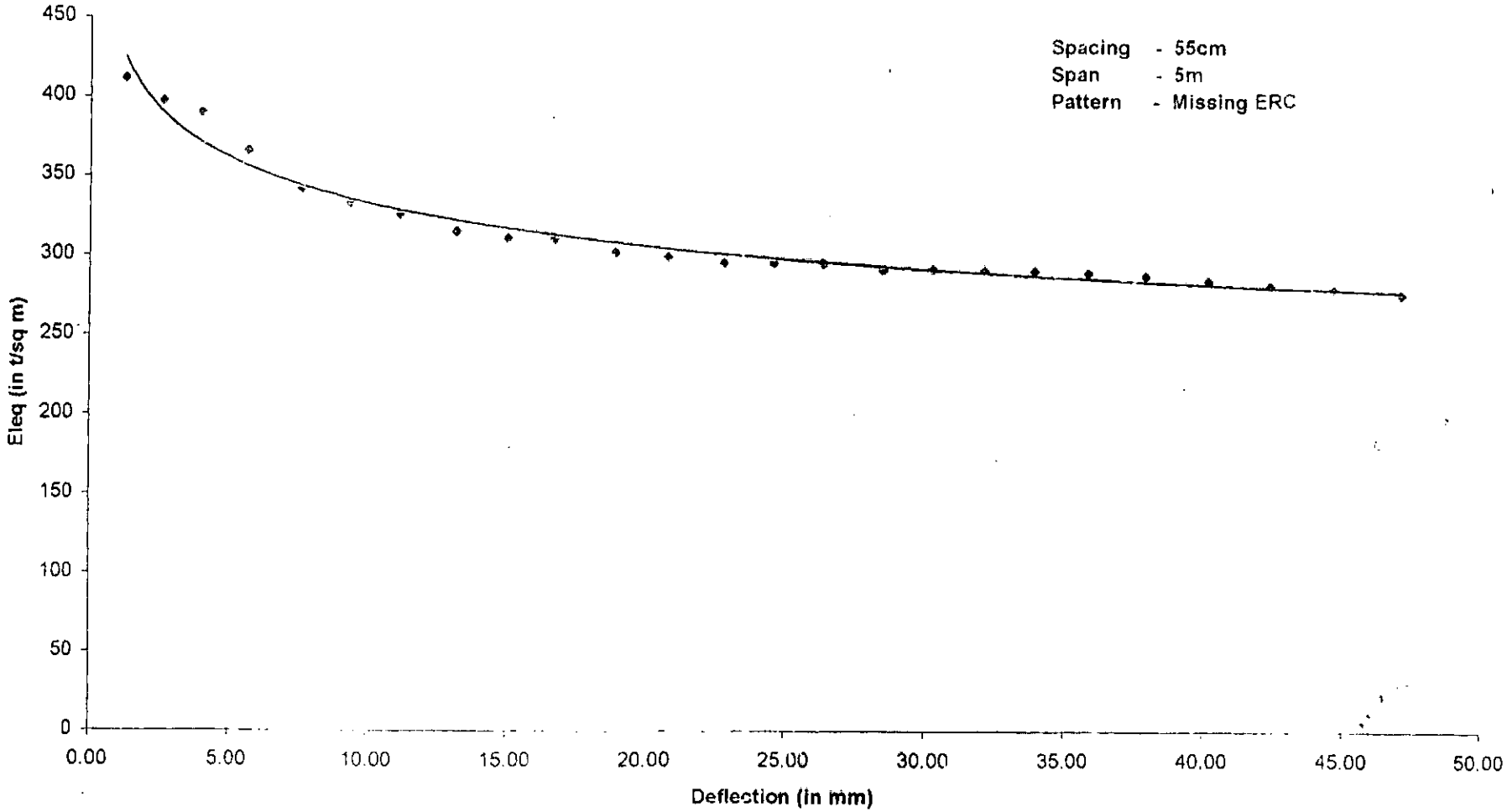
Table 5 : Showing Load, measured deflections and calculated Eleq

05120



Graph 5A : **Load Vs Deflection**

05121



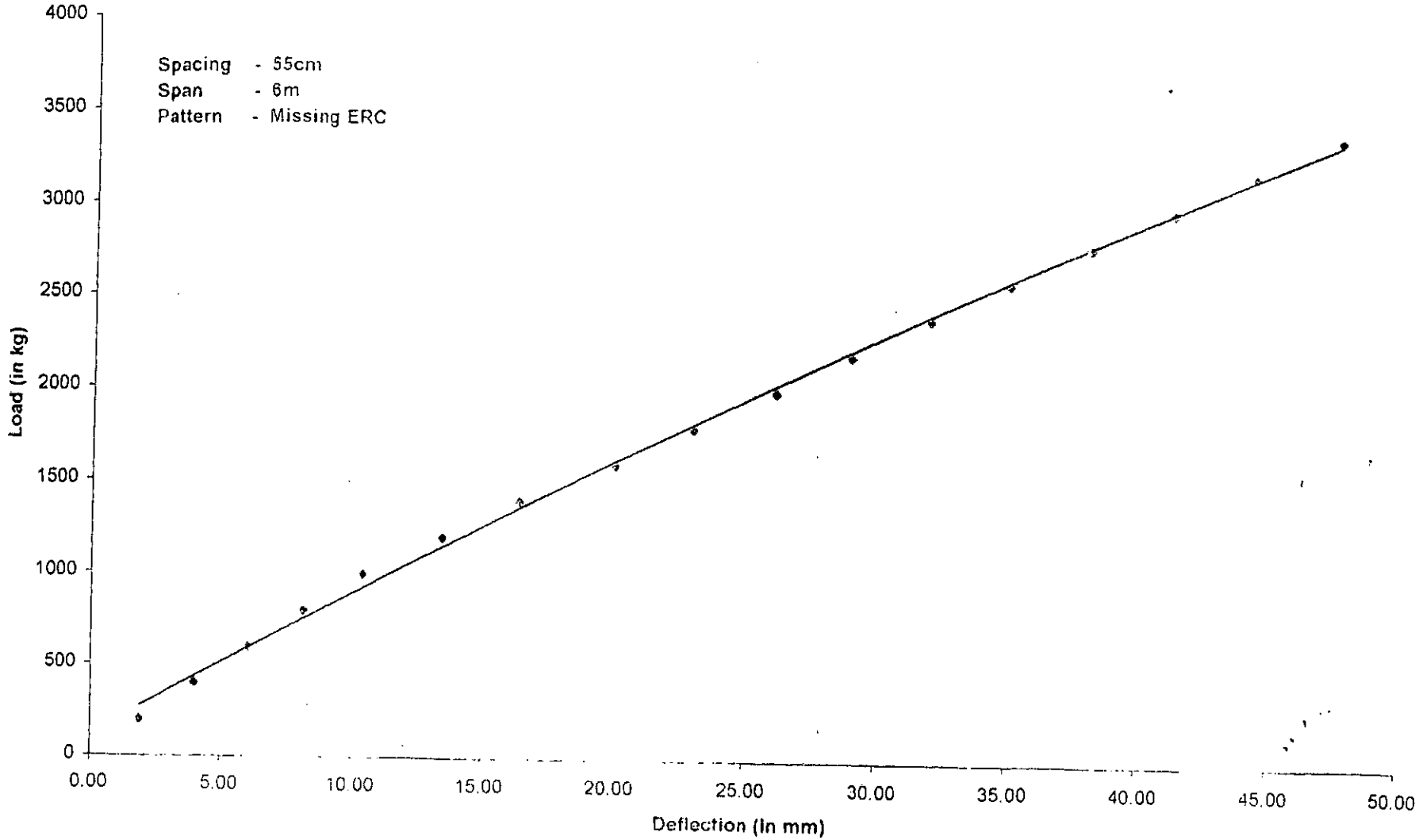
Graph 5B : **Deflection Vs Eleq**

05122

Spacing - 55cm
Span - 6m
Pattern - Missing ERC

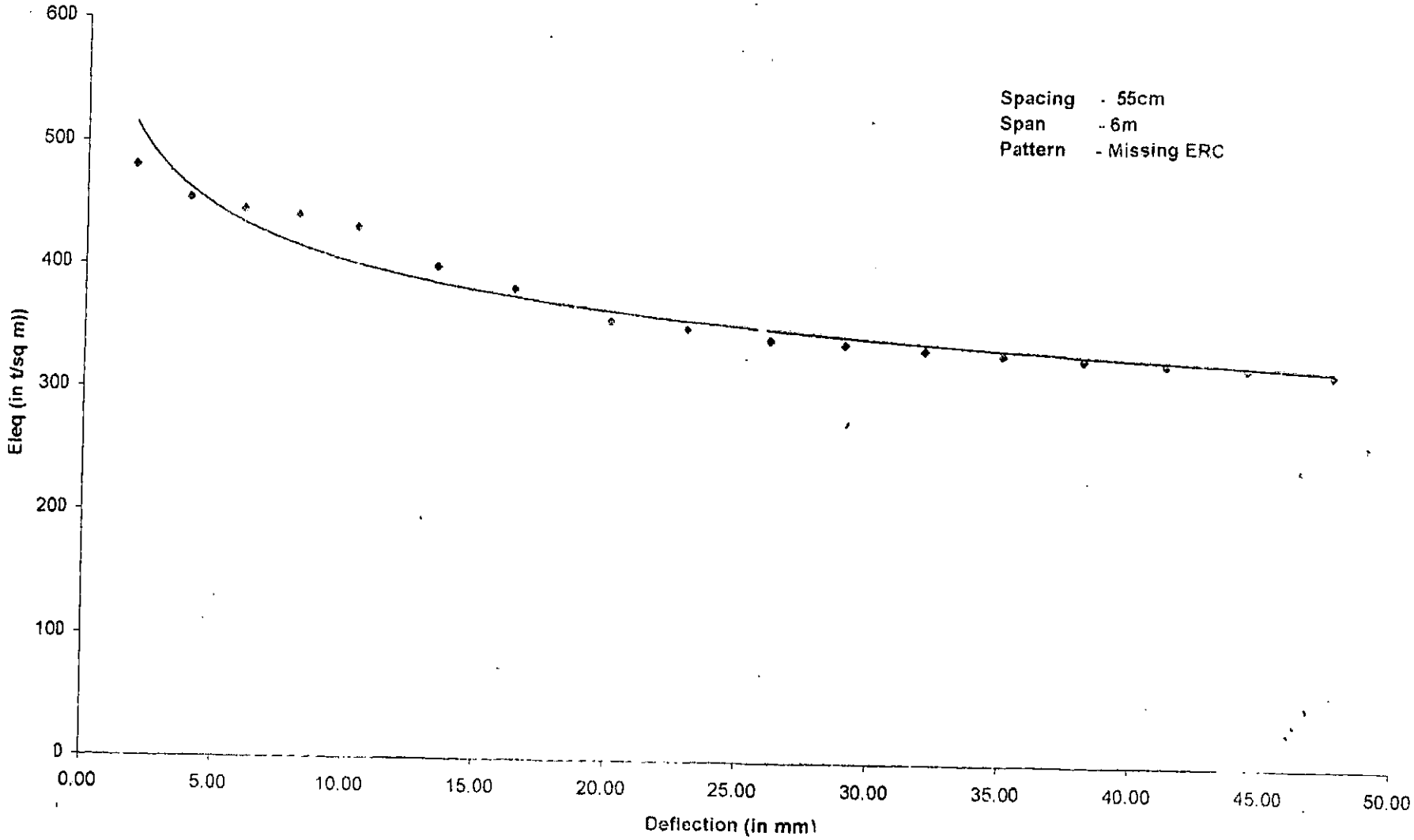
S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	1.88	1.86	1.87	481
2	400	4.01	3.90	3.96	455
3	600	6.15	5.95	6.05	446
4	800	8.40	7.90	8.15	442
5	1000	10.72	10.10	10.41	432
6	1200	13.90	13.05	13.48	401
7	1400	16.95	15.90	16.43	384
8	1600	20.65	19.55	20.10	358
9	1800	23.55	22.50	23.03	352
10	2000	26.85	25.50	26.18	344
11	2200	29.70	28.35	29.03	341
12	2400	32.85	31.25	32.05	337
13	2600	35.90	34.20	35.05	334
14	2800	39.10	37.15	38.13	330
15	3000	42.32	40.25	41.29	327
16	3200	45.60	43.20	44.40	324
17	3400	48.95	46.45	47.70	321

Table 6 : Showing Load, measured deflections and calculated Eleq



Graph 6A : Load Vs Deflection

05124



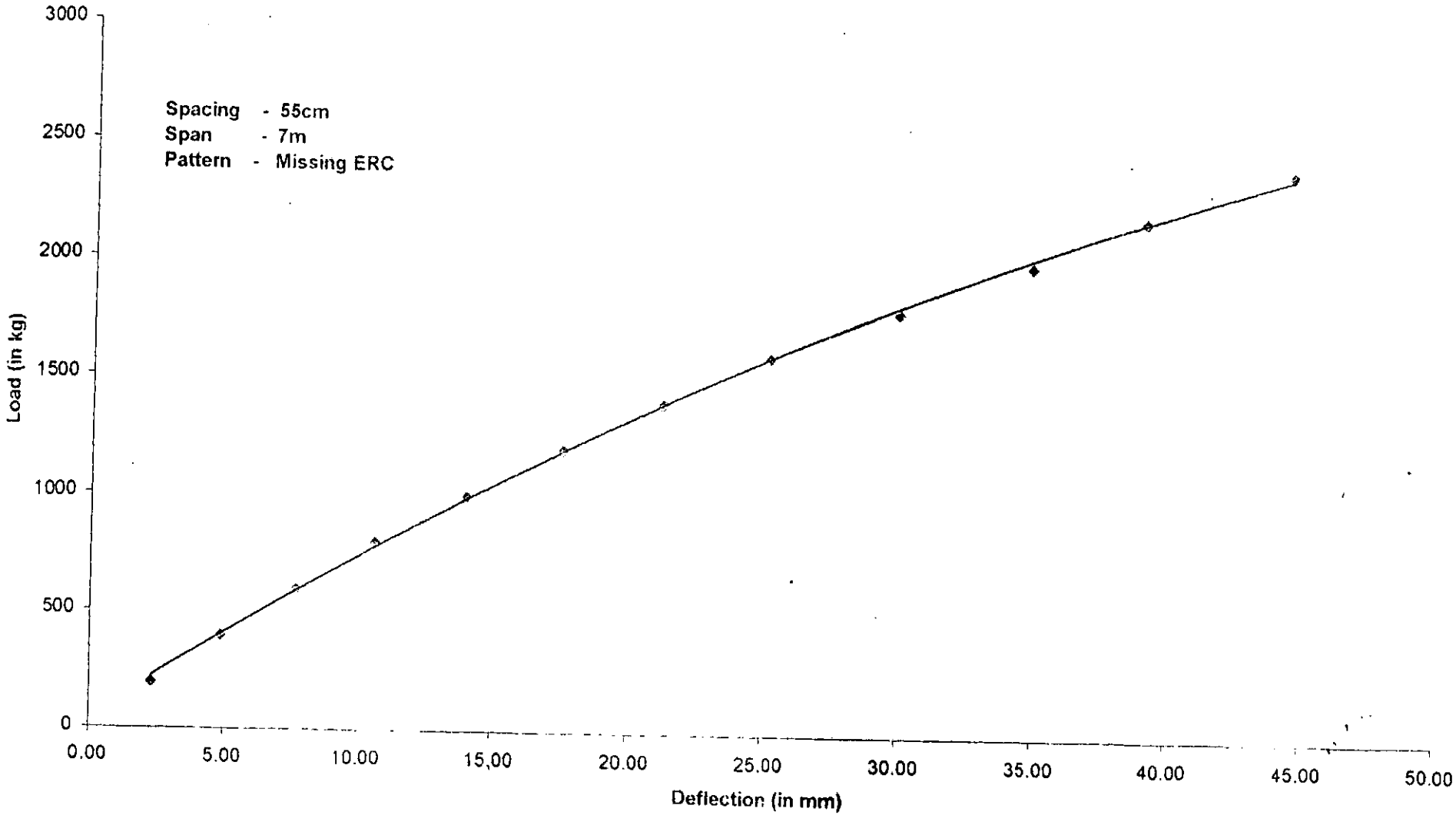
Graph 6B : **Deflection Vs Eleq**

05125

Spacing - 55cm
Span - 7m
Pattern - Missing ERC

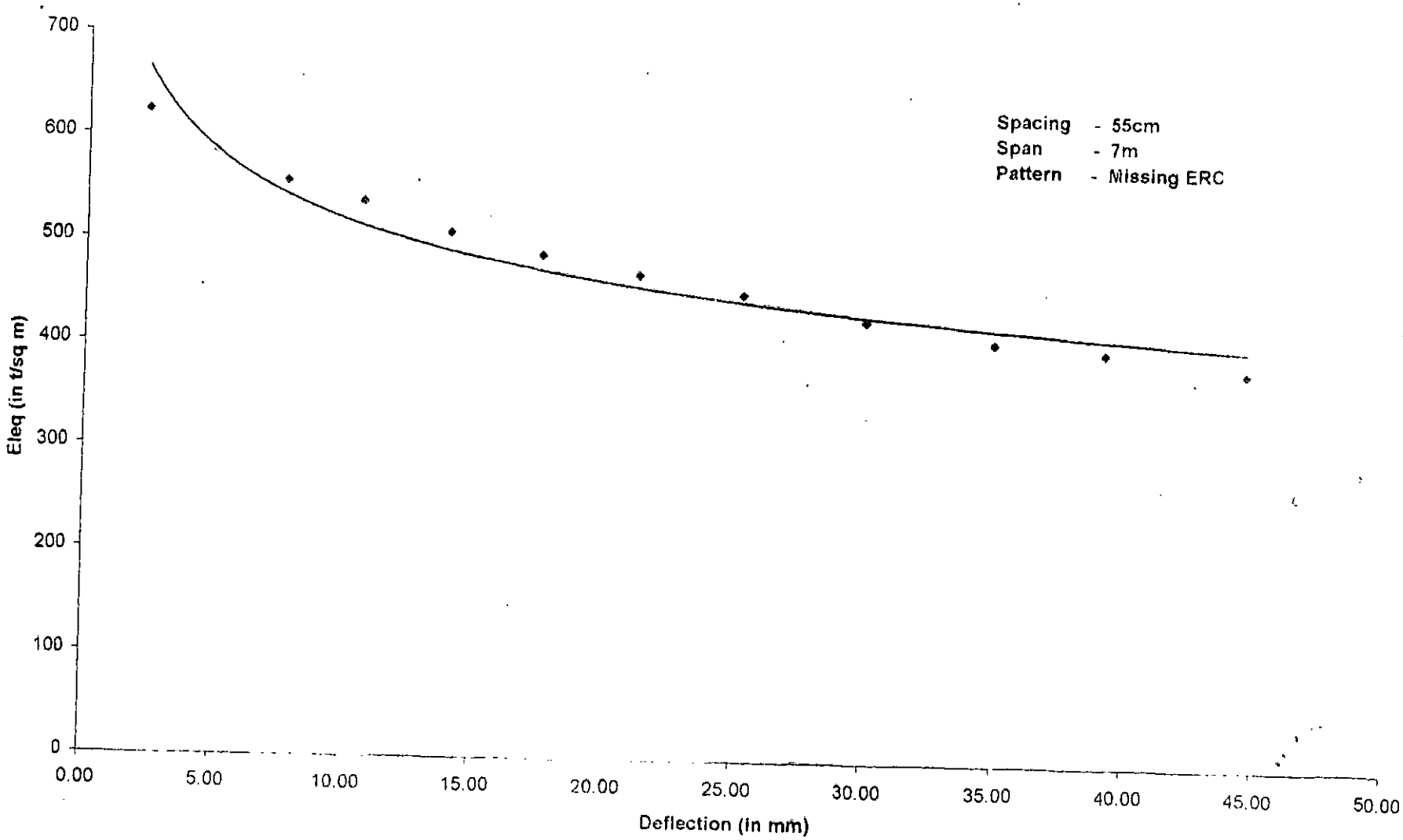
S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	2.30	2.28	2.29	624
2	400	4.95	4.80	4.88	586
3	600	7.88	7.50	7.69	558
4	800	11.05	10.20	10.63	538
5	1000	14.55	13.50	14.03	510
6	1200	18.10	17.00	17.55	489
7	1400	21.85	20.65	21.25	471
8	1600	25.95	24.50	25.23	453
9	1800	30.85	29.10	29.98	429
10	2000	35.90	33.90	34.90	410
11	2200	40.20	38.10	39.15	402
12	**2400**	**45.70**	**43.50**	**44.60**	**385**

Table 7 : Showing Load, measured deflections and calculated Eieq



Graph 7A : Load Vs Deflection

05127



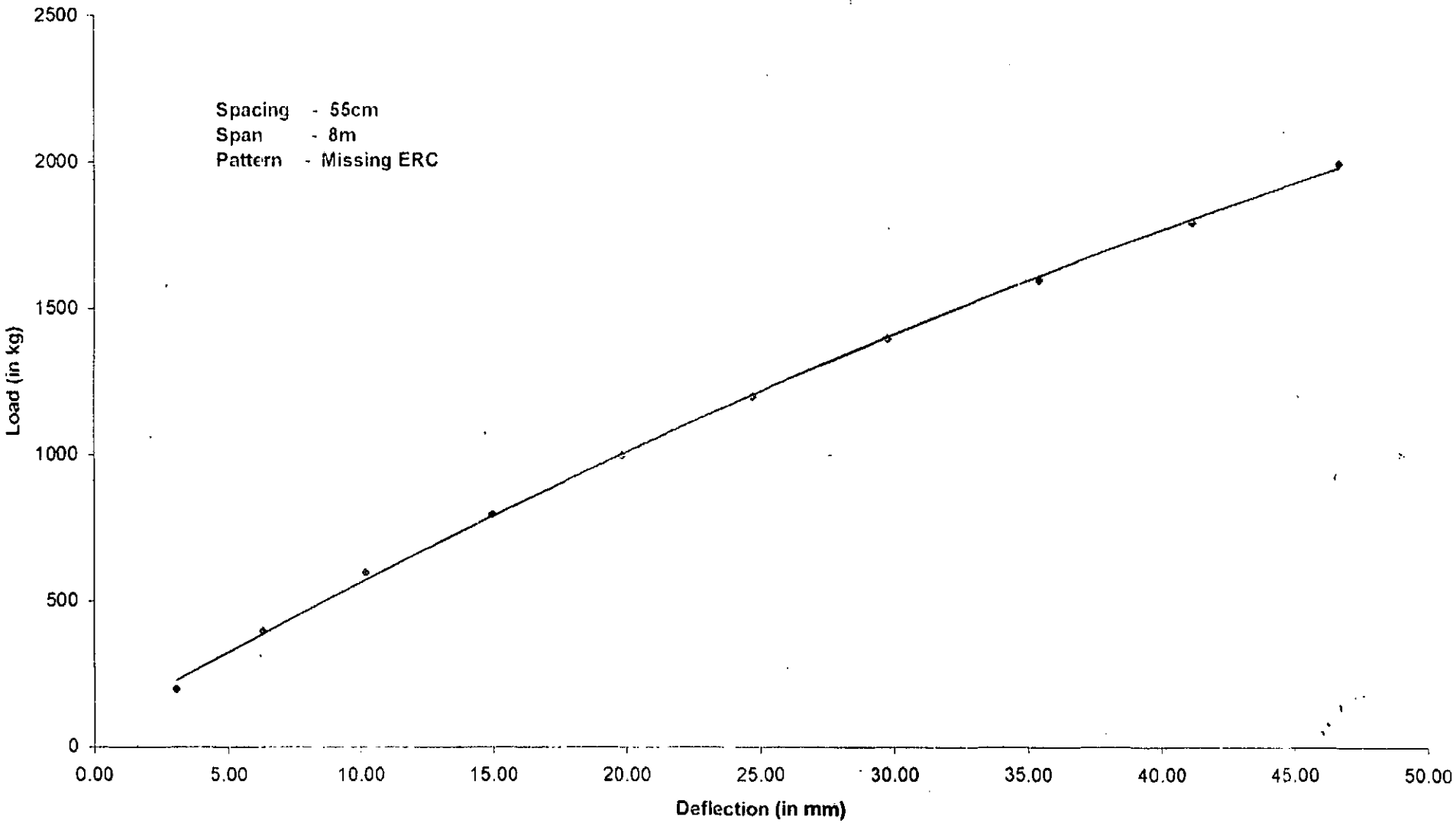
Graph7B : Deflection Vs Eleq

05128

Spacing - 55cm
Span - 8m
Pattern - Missing ERC

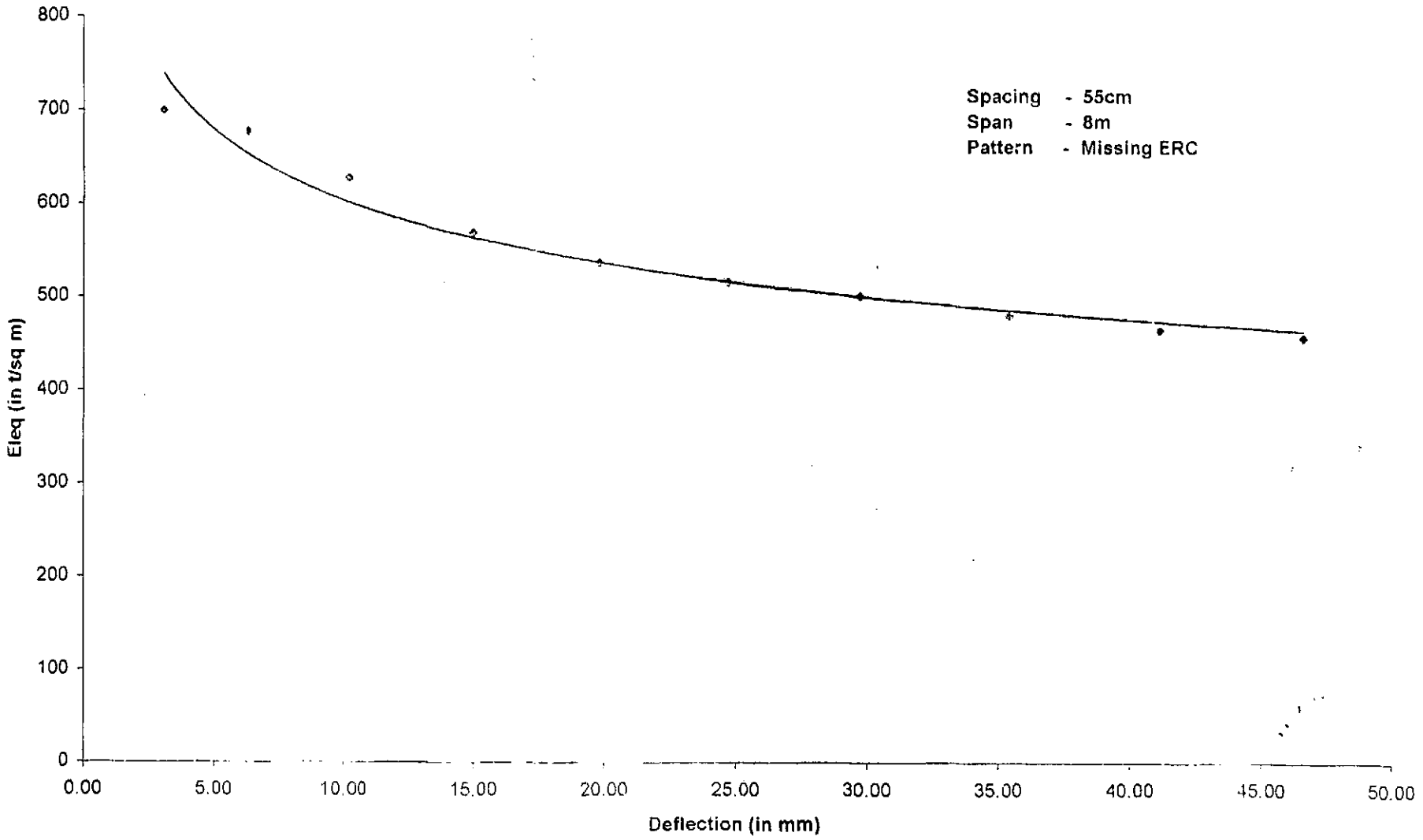
S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	3.05	3.05	3.05	699
2	400	6.35	6.25	6.30	677
3	600	10.45	9.95	10.20	627
4	800	15.5	14.50	15.00	569
5	1000	20.45	19.30	19.88	537
6	1200	25.4	24.10	24.75	517
7	1400	30.65	28.95	29.80	501
8	1600	36.5	34.45	35.48	481
9	1800	42.3	40.10	41.20	466
10	**2000**	**47.9**	**45.50**	46.70	**457**

Table 8 : Showing Load, measured deflections and calculated Eleq



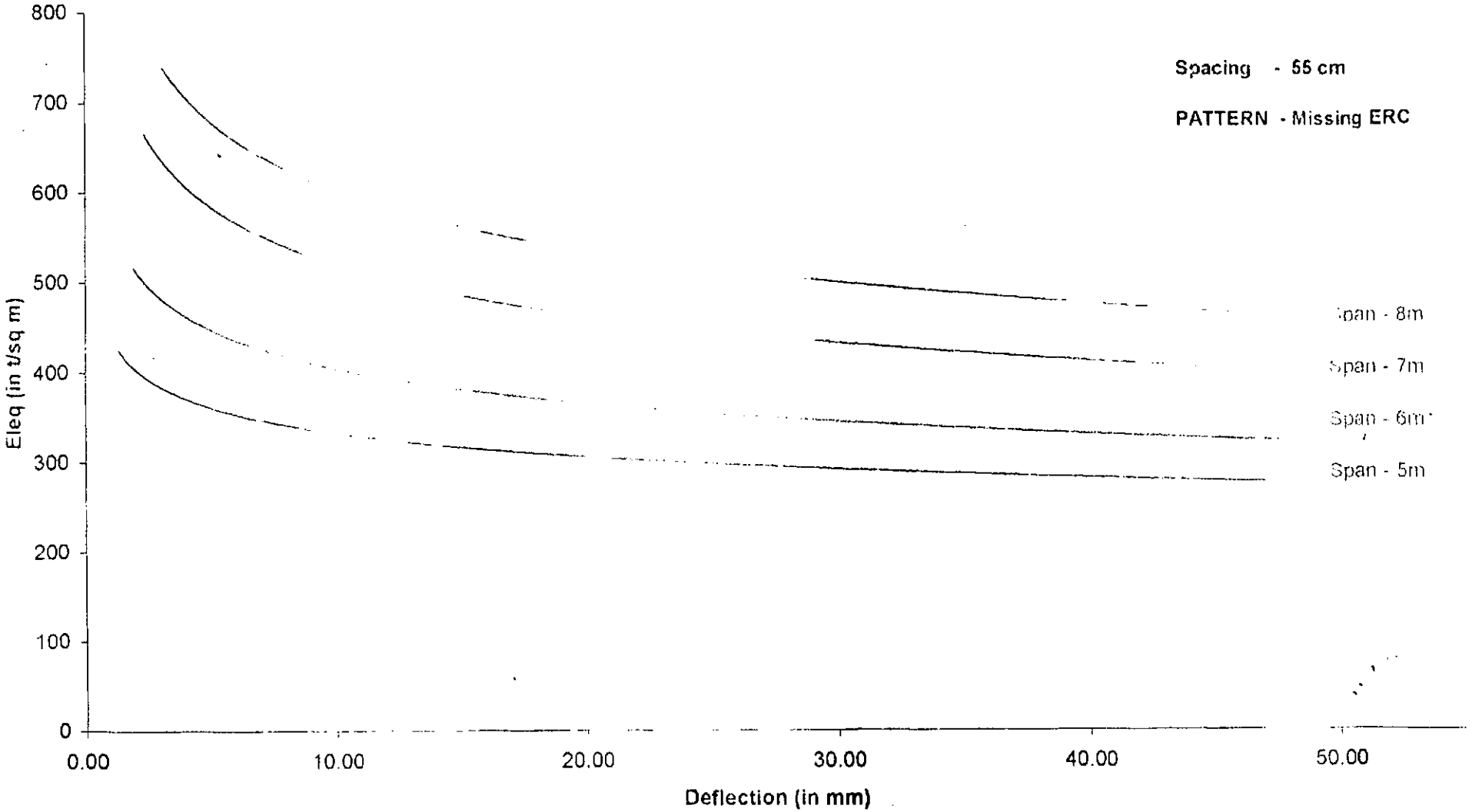
Graph 8A : Load Vs Deflection

05130



Graph 8B : **Deflection Vs Eleq**

05131



Graph : Combined Deflection Vs Eleq

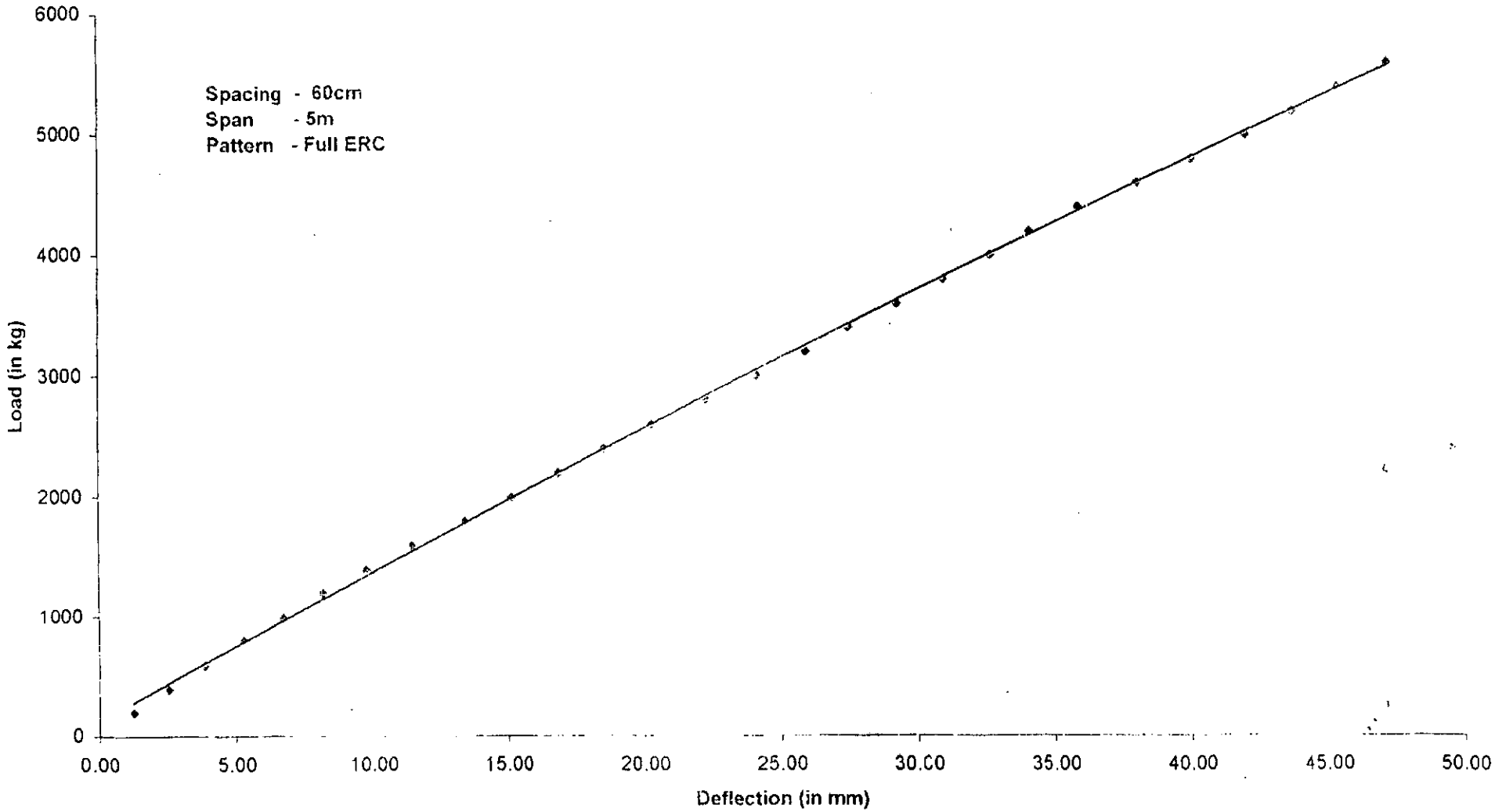
05132

Spacing - 60cm
Span - 5m
Pattern - Full ERC

S.No.	Load (Kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	EI (t/sq m)
1	200	1.22	1.20	1.21	430
2	400	2.55	2.52	2.54	411
3	600	3.91	3.80	3.86	405
4	800	5.35	5.20	5.28	395
5	1000	6.80	6.60	6.70	389
6	1200	8.30	8.01	8.16	383
7	1400	9.95	9.55	9.75	374
8	1600	11.69	11.15	11.42	365
9	1800	13.70	13.10	13.40	350
10	2000	15.23	15.02	15.13	344
11	2200	17.15	16.60	16.88	340
12	2400	18.95	18.15	18.55	337
13	2600	20.75	19.85	20.30	334
14	2800	22.88	21.68	22.28	327
15	3000	24.83	23.50	24.17	323
16	3200	26.65	25.20	25.93	321
17	3400	28.25	26.75	27.50	322
18	3600	30.11	28.44	29.28	320
19	3800	31.85	30.12	30.99	319
20	4000	33.60	31.80	32.70	319
21	4200	35.10	33.16	34.13	320
22	4400	36.92	34.90	35.91	319
23	4600	39.15	36.98	38.1	317
24	4800	41.18	38.9	40.0	317
25	5000	43.25	40.85	42.1	316
26	5200	44.95	42.48	43.7	310
27	5400	46.70	44.1	45.4	310
28	5600	**48.60**	**45.85**	**47.2**	**309**

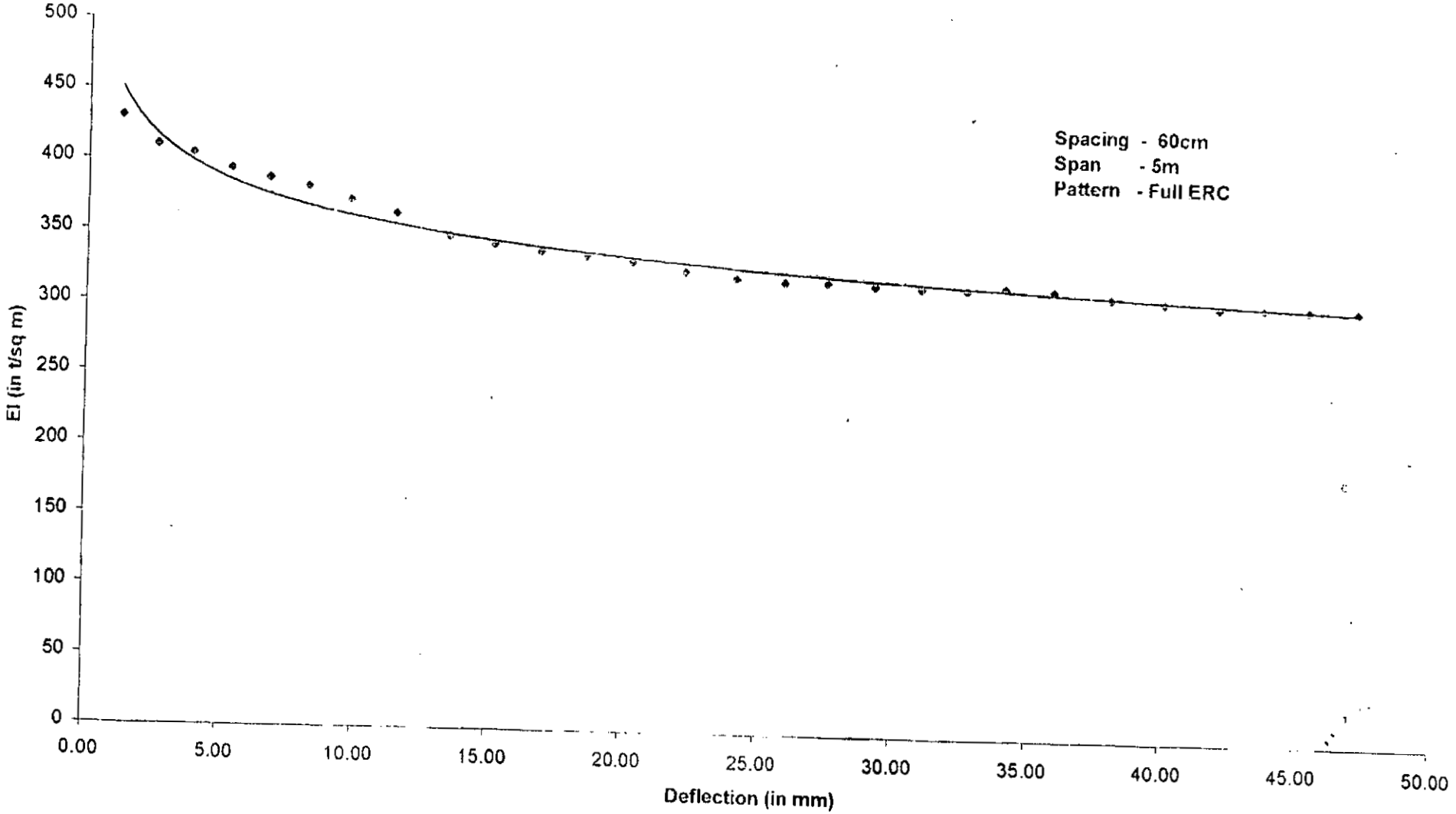
Table 9 : Showing Load, measured deflections and calculated EI

05133



Graph 9A : Load Vs Deflection

05134



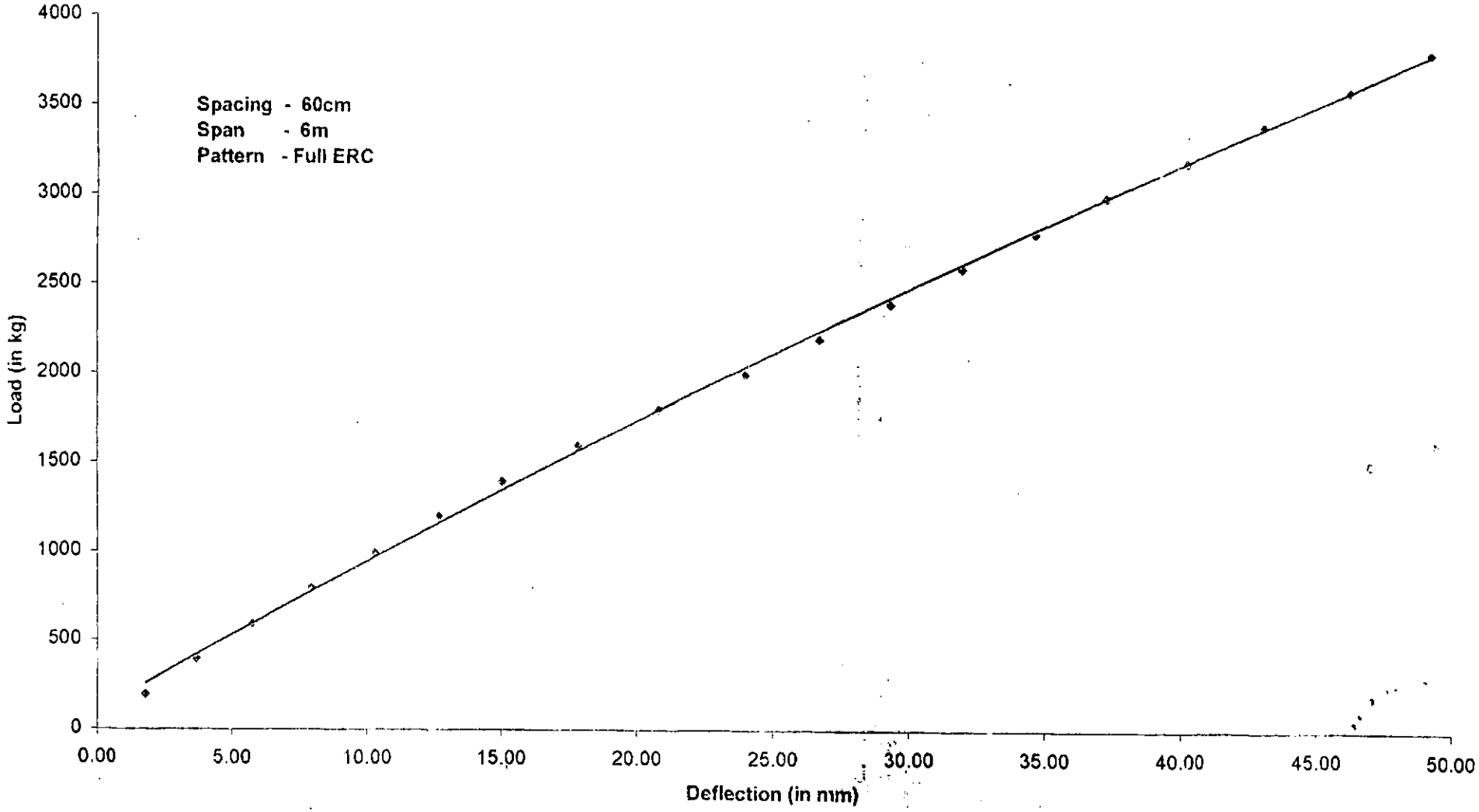
Graph 9B : Deflection Vs Eleq

05135

Spacing - 60cm
Span - 6m
Pattern - Full ERC

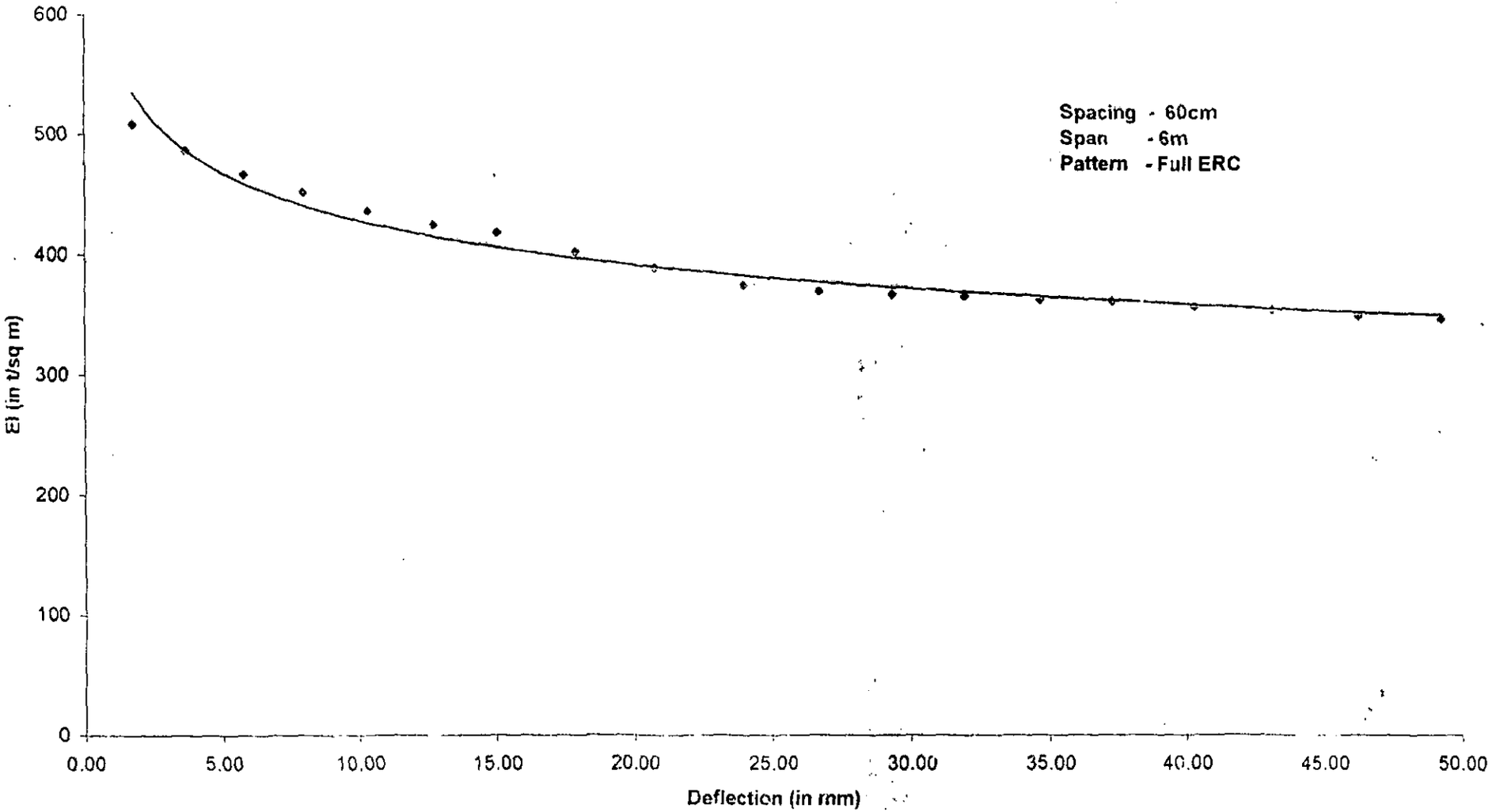
S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	EI (t/sq m)
1	200	1.78	1.76	1.77	508
2	400	3.70	3.68	3.69	488
3	600	5.85	5.70	5.78	468
4	800	8.10	7.80	7.95	453
5	1000	10.50	10.10	10.30	437
6	1200	12.85	12.52	12.69	426
7	1400	15.20	14.85	15.03	419
8	1600	18.10	17.60	17.85	403
9	1800	21.06	20.55	20.81	389
10	2000	24.35	23.65	24.00	375
11	2200	27.12	26.35	26.74	370
12	2400	29.72	29.03	29.38	368
13	2600	32.45	31.55	32.00	366
14	2800	35.25	34.20	34.73	363
15	3000	37.90	36.80	37.35	361
16	3200	40.92	39.72	40.32	357
17	3400	43.70	42.62	43.16	354
18	3600	46.87	45.80	46.34	350
19	3800	49.95	48.80	49.38	346

Table 10 : Showing Load, measured deflections and calculated EI



Graph 10A : Load Vs Deflection

05137



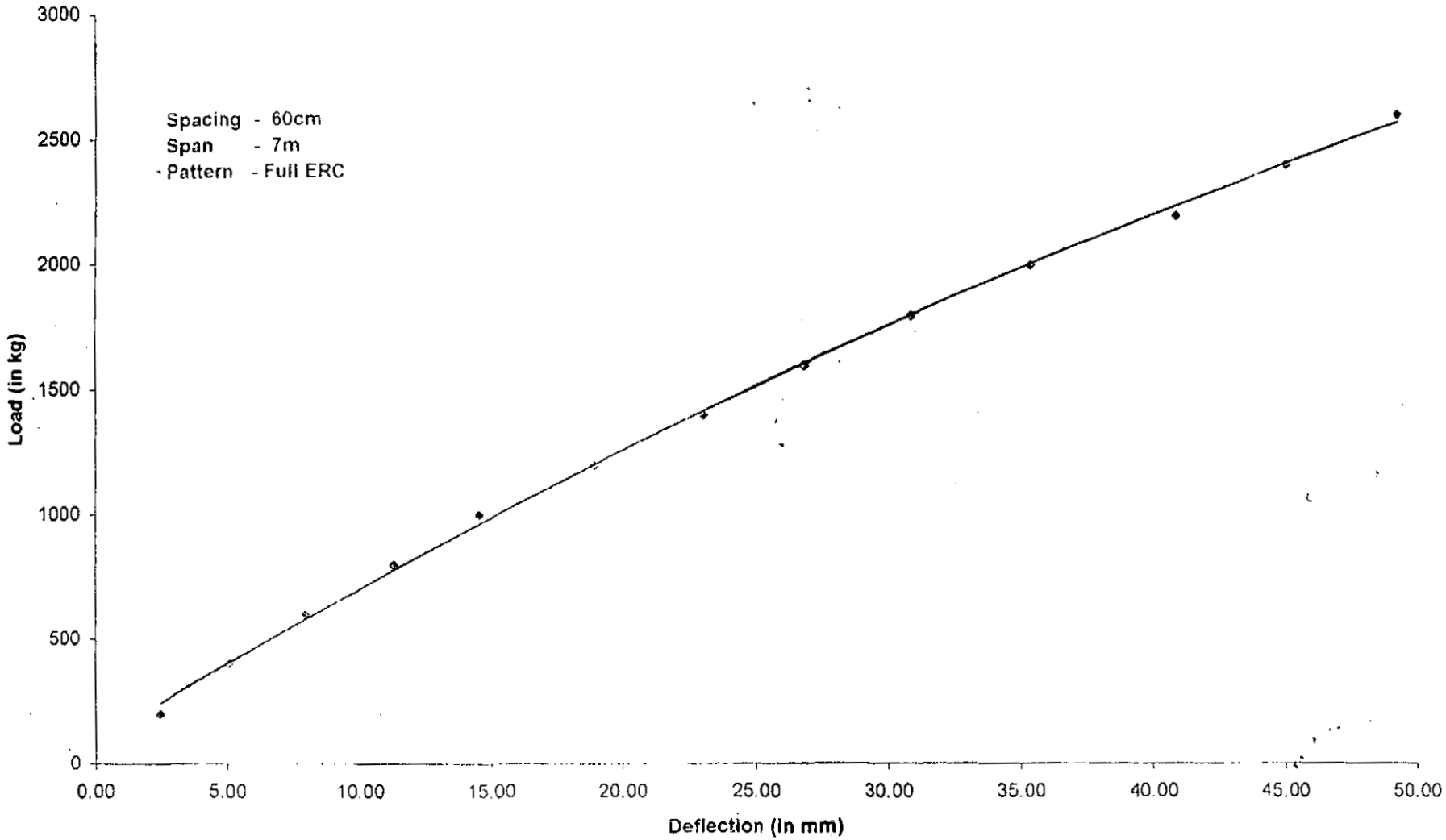
Graph 10B : Deflection Vs Eleq

05138

Spacing - 60cm
Span - 7m
Pattern - Full ERC

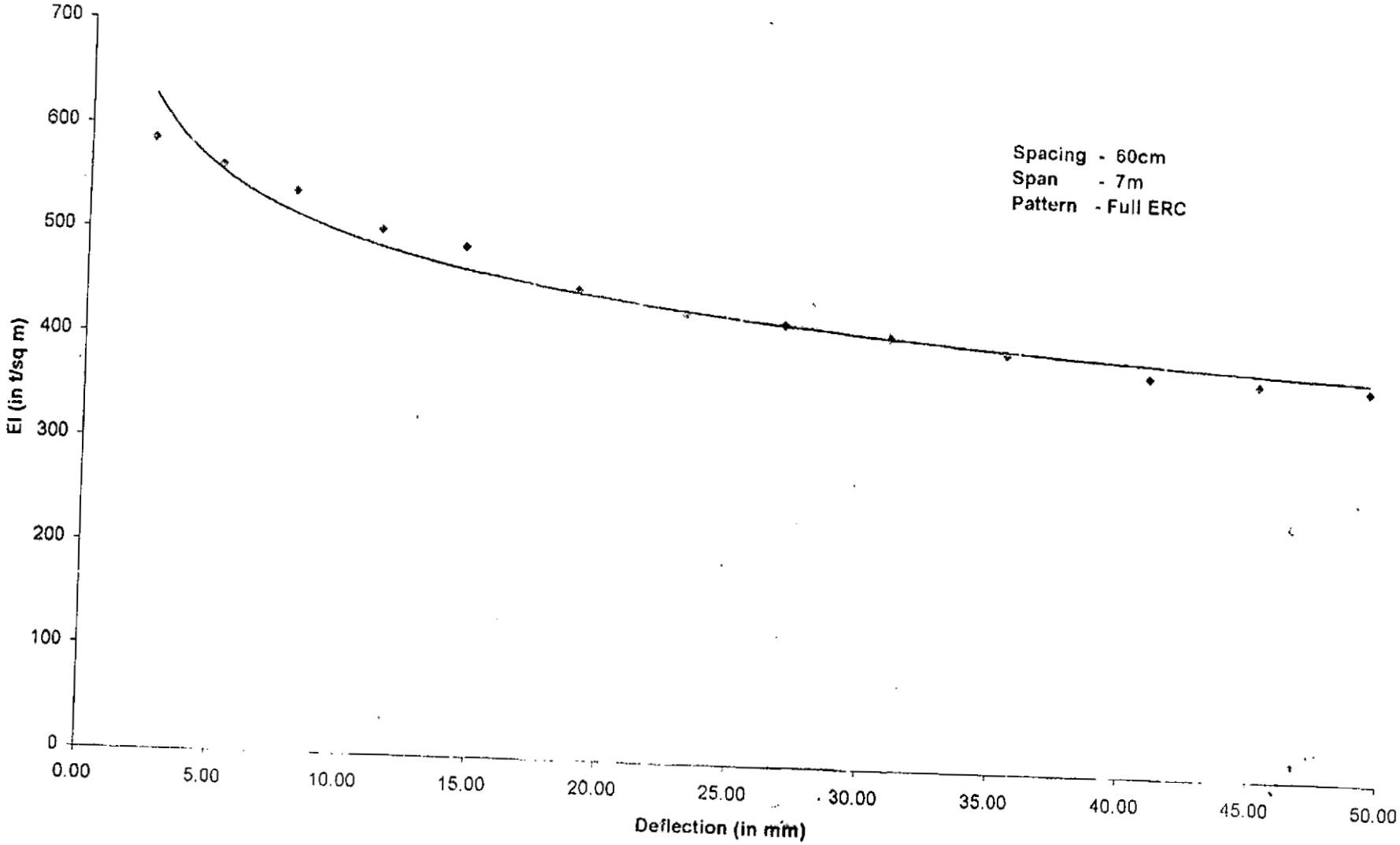
S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	EI (t/sq m)
1	200	2.45	2.42	2.44	587
2	400	5.10	5.05	5.08	563
3	600	8.10	7.80	7.95	539
4	800	11.60	11.05	11.33	505
5	1000	15.60	13.55	14.58	490
6	1200	20.12	17.80	18.96	452
7	1400	24.30	21.95	23.13	433
8	1600	28.15	25.70	26.93	425
9	1800	32.15	29.80	30.98	415
10	2000	36.65	34.35	35.50	403
11	2200	41.75	40.20	40.98	384
12	2400	45.90	44.45	45.18	380
13	**2600**	**50.20**	**48.75**	**49.48**	**376**

Table 11 : Showing Load, measured deflections and calculated EI



Graph 11A : **Load Vs Deflection**

05140



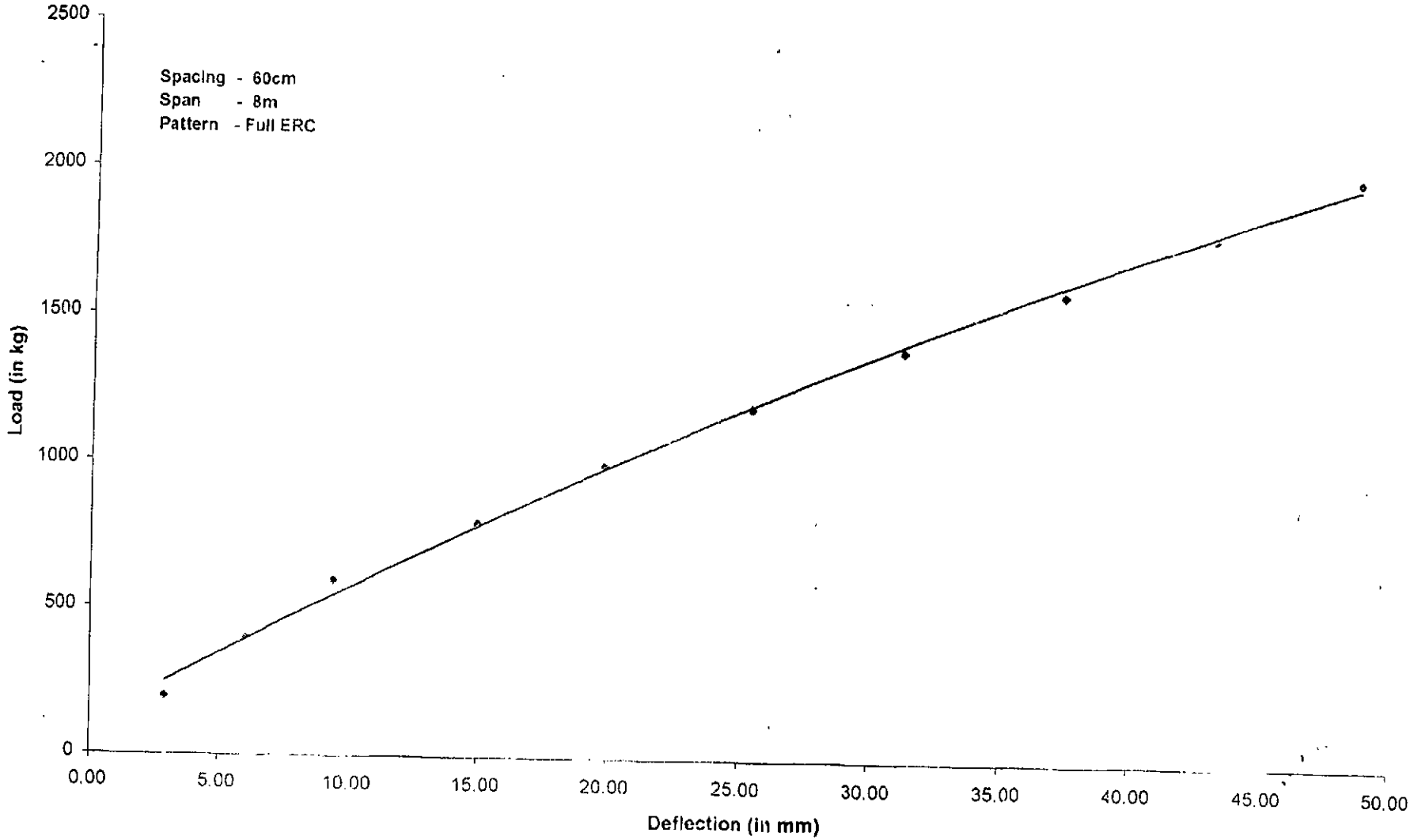
Graph 11B : Deflection Vs Eleq

05141

Spacing - 60cm
Span - 8m
Pattern - Full ERC

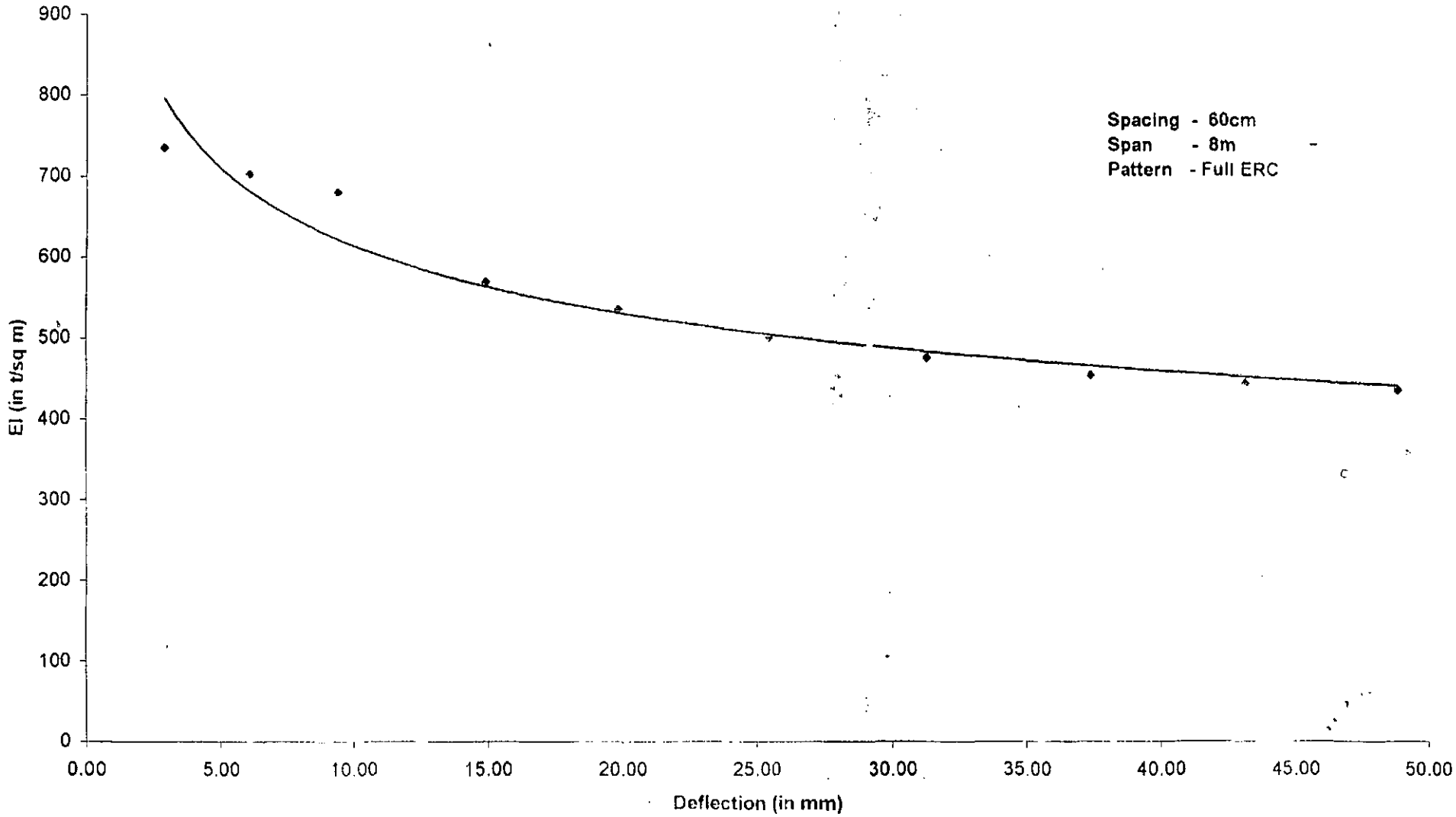
S.No.	Load (Kg)	Def 1(mm)	Def 2 (mm)	Avg Def (mm)	EI (t/sq m)
1	200	2.90	2.90	2.90	736
2	400	6.10	6.03	6.07	703
3	600	9.40	9.40	9.40	681
4	800	15.05	14.85	14.95	571
5	1000	20.45	19.25	19.85	537
6	1200	26.19	24.80	25.50	502
7	1400	32.08	30.65	31.37	476
8	1600	38.25	36.75	37.50	455
9	1800	44.10	42.35	43.23	444
10	**2000**	**49.85**	**47.95**	**48.90**	**436**

Table 12 : Showing Load, measured deflections and calculated EI



Graph 12A : **Load Vs Deflection**

05143



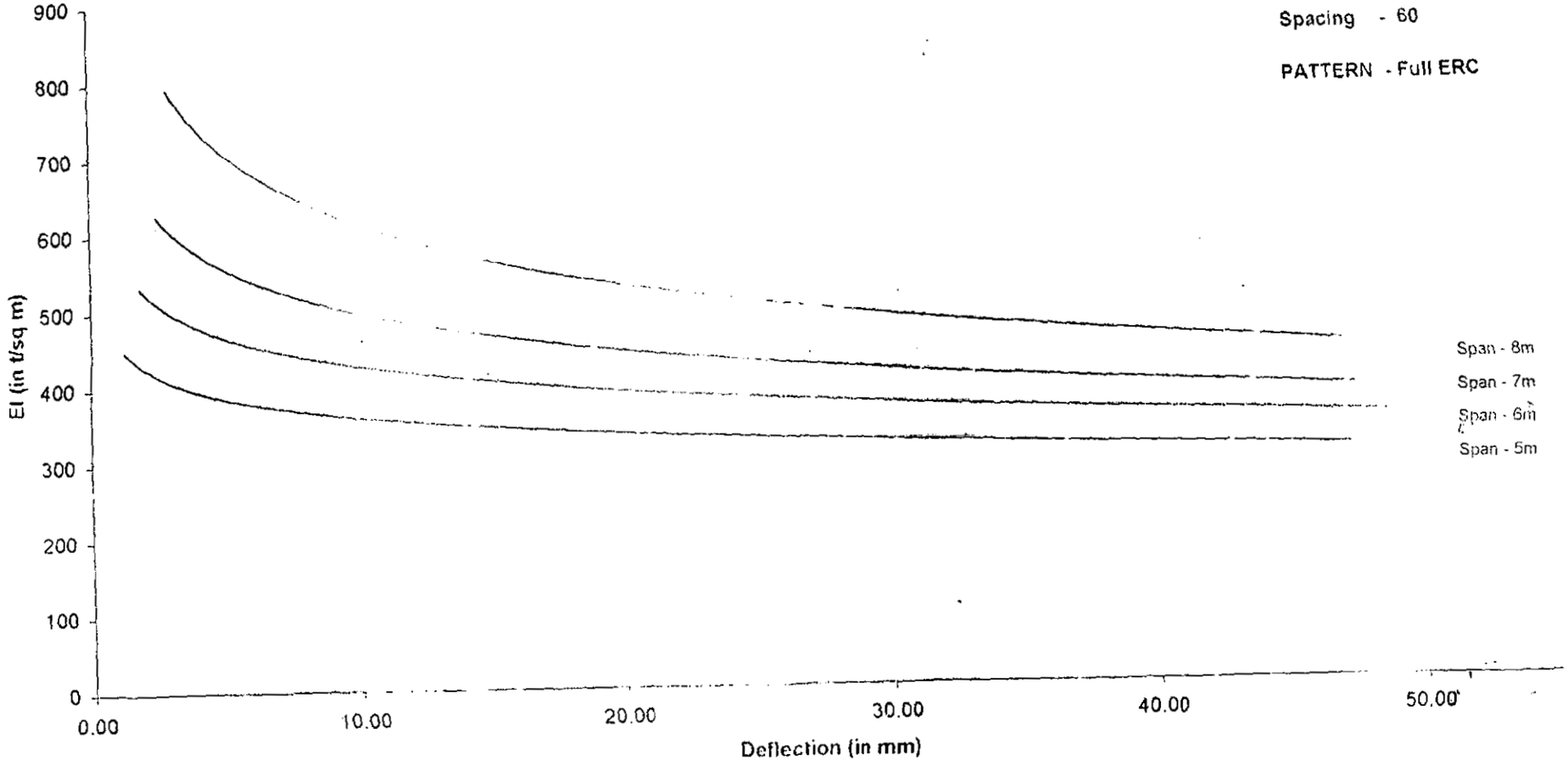
Graph 12B :Deflection Vs Eleq

05144

Spacing - 60cm
Span - 5m
Pattern - Missing ERC

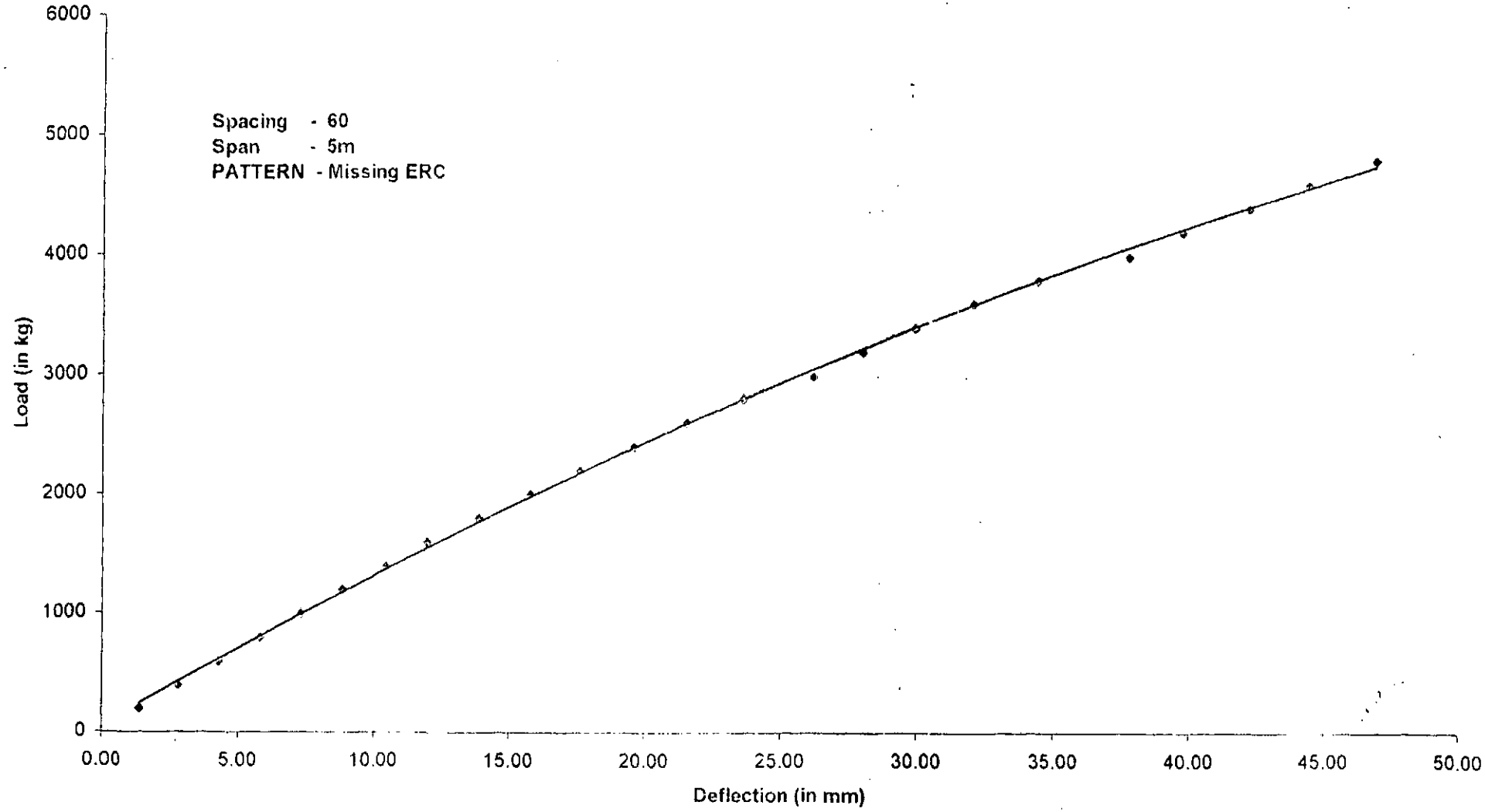
S.No.	Load (Kg)	Def 1 (mm)	Def 2 (mm)	Avg Def(mm)	Eleq (t/sq m)
1	200	1.38	1.36	1.37	380
2	400	2.86	2.75	2.81	371
3	600	4.4	4.16	4.28	365
4	800	5.90	5.72	5.81	359
5	1000	7.52	7.10	7.31	356
6	1200	9.14	8.55	8.85	353
7	1400	10.82	10.15	10.49	348
8	1600	12.32	11.70	12.01	347
9	1800	14.35	13.50	13.93	337
10	2000	16.25	15.42	15.84	329
11	2200	18.15	17.20	17.68	324
12	2400	20.20	19.15	19.68	318
13	2600	22.15	21.10	21.63	313
14	2800	24.30	23.05	23.68	308
15	3000	26.92	25.60	26.26	298
16	3200	28.78	27.36	28.07	297
17	3400	30.75	29.30	30.03	295
18	3600	32.90	31.40	32.15	292
19	3800	35.25	33.74	34.50	287
20	4000	38.72	37.02	37.87	275
21	4200	40.92	38.80	39.86	274
22	4400	43.45	41.15	42.30	271
23	4600	45.64	43.39	44.52	269
24	4800	48.25	45.85	47.05	266

Table 13 : Showing Load, measured deflections and calculated Eleq



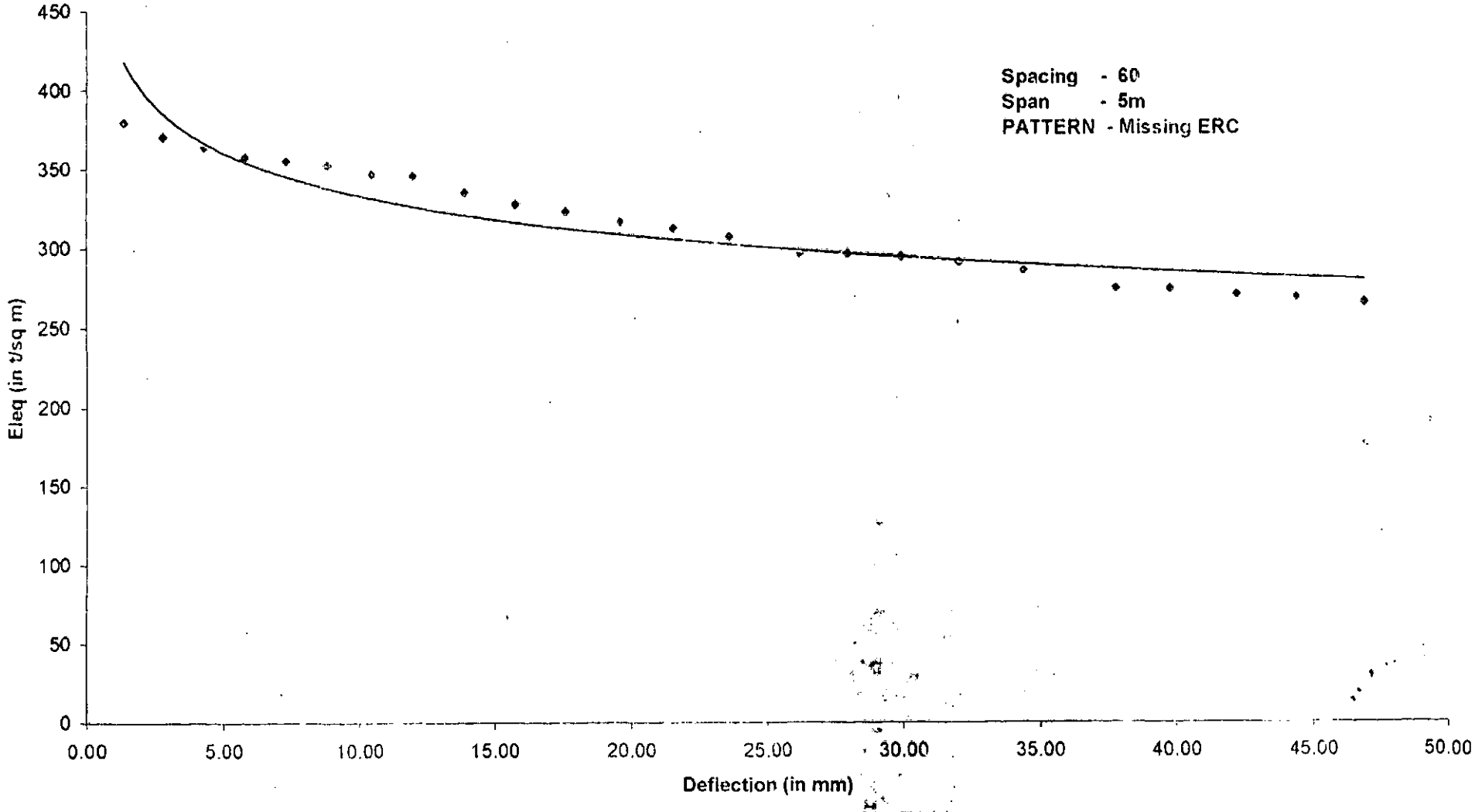
Graph : Combined Deflection Vs EI

05146



Graph 13A : Load Vs Deflection

05147



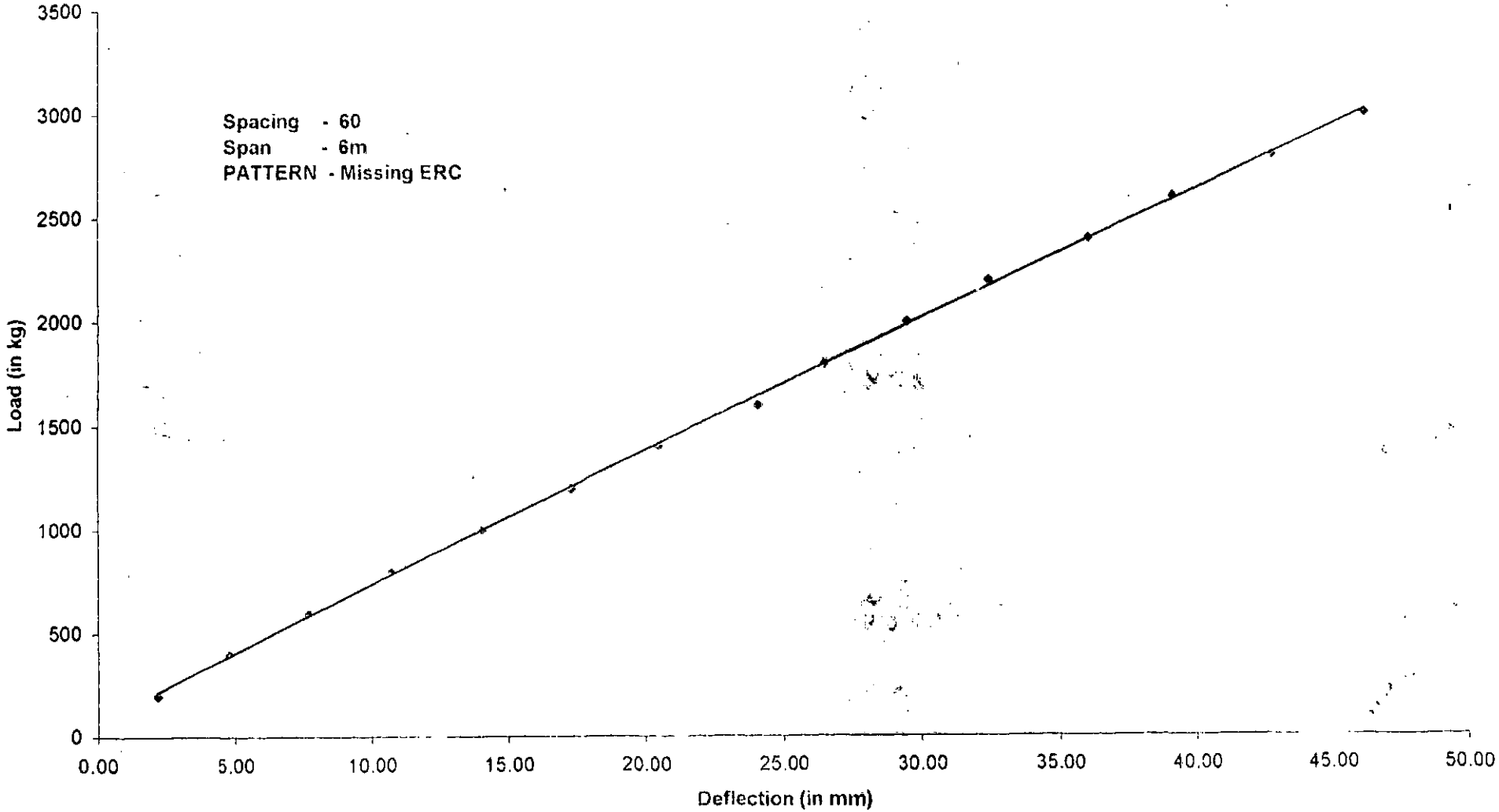
Graph 13B : Deflection Vs Eleq

05148

Spacing - 60cm
Span - 6m
Pattern - Missing ERC

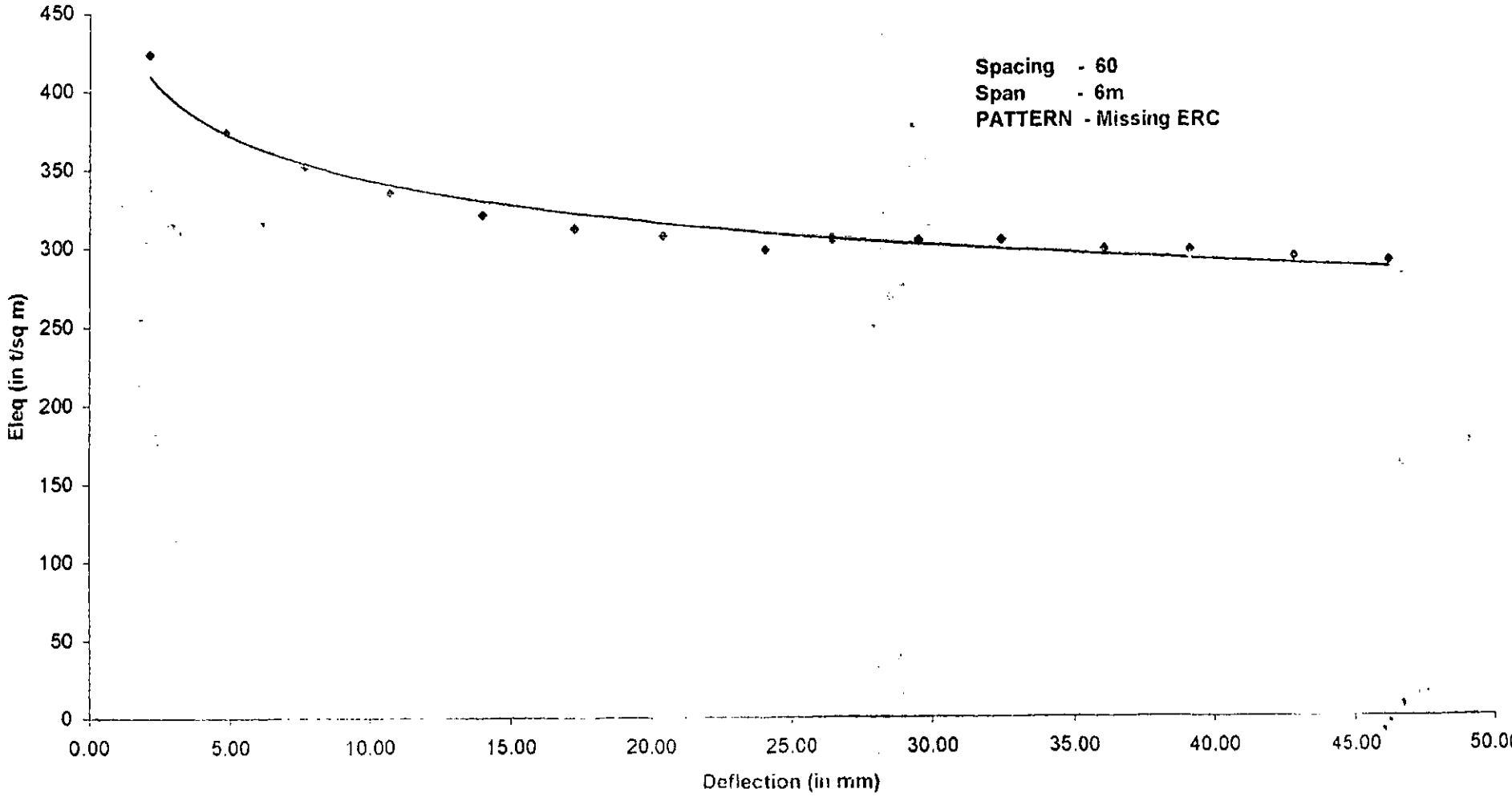
S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	2.12	2.12	2.12	425
2	400	5.30	4.31	4.81	375
3	600	8.20	7.15	7.68	352
4	800	11.28	10.20	10.74	335
5	1000	14.60	13.45	14.03	321
6	1200	17.88	16.73	17.31	312
7	1400	21.15	19.85	20.50	307
8	1600	24.81	23.40	24.11	299
9	1800	27.16	25.85	26.51	306
10	2000	30.20	28.88	29.54	305
11	2200	33.05	31.90	32.48	305
12	2400	36.54	35.77	36.16	299
13	2600	39.82	38.64	39.23	298
14	2800	43.56	42.25	42.91	294
15	**3000**	**47.06**	**45.55**	**46.31**	**292**

Table 14 : Showing Load, measured deflections and calculated Eleq



Graph 14A : Load Vs Deflection

05150



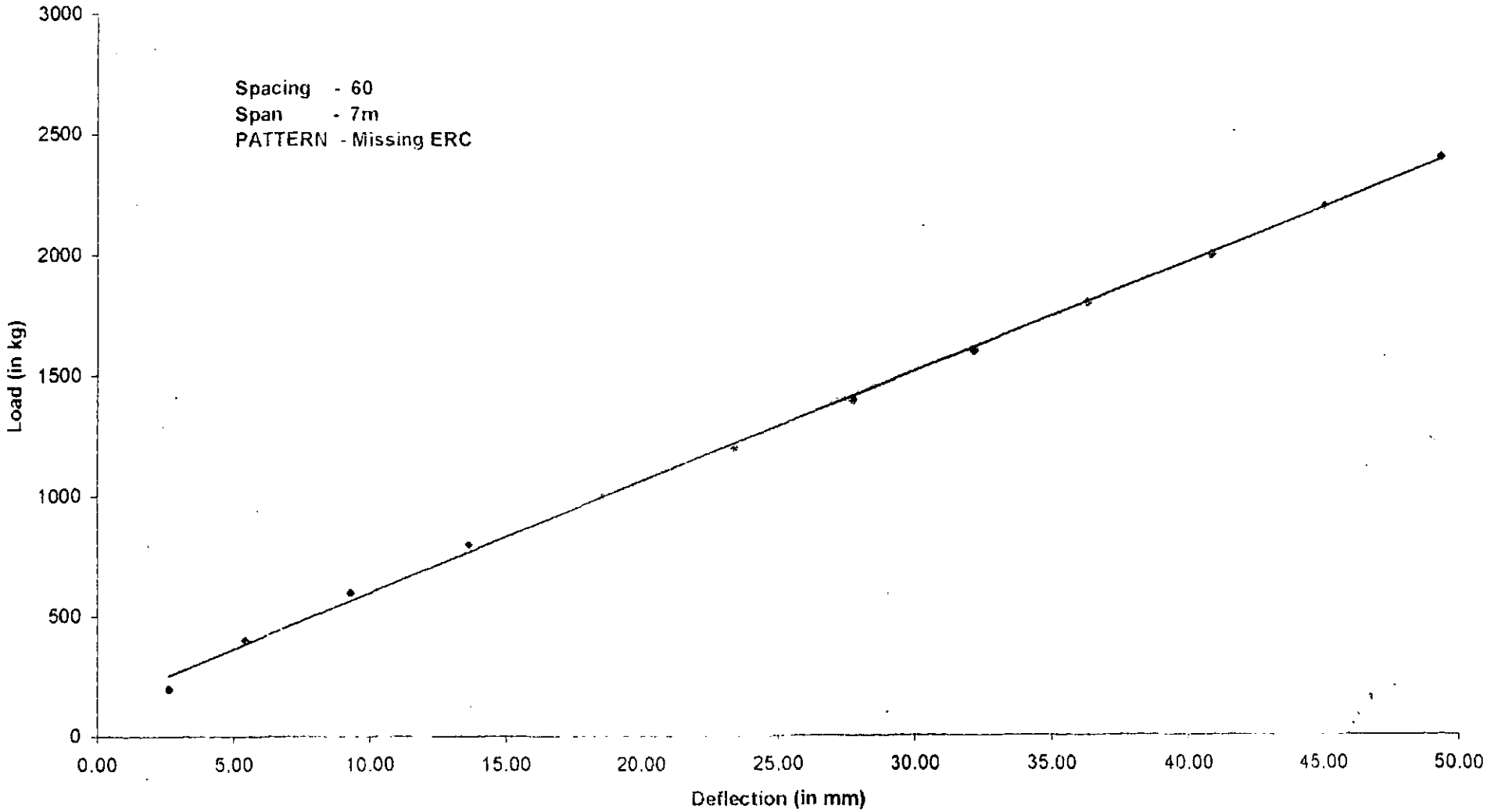
Graph 14B : Deflection Vs Eleq

05151

Spacing - 60cm
Span - 7m
Pattern - Missing ERC

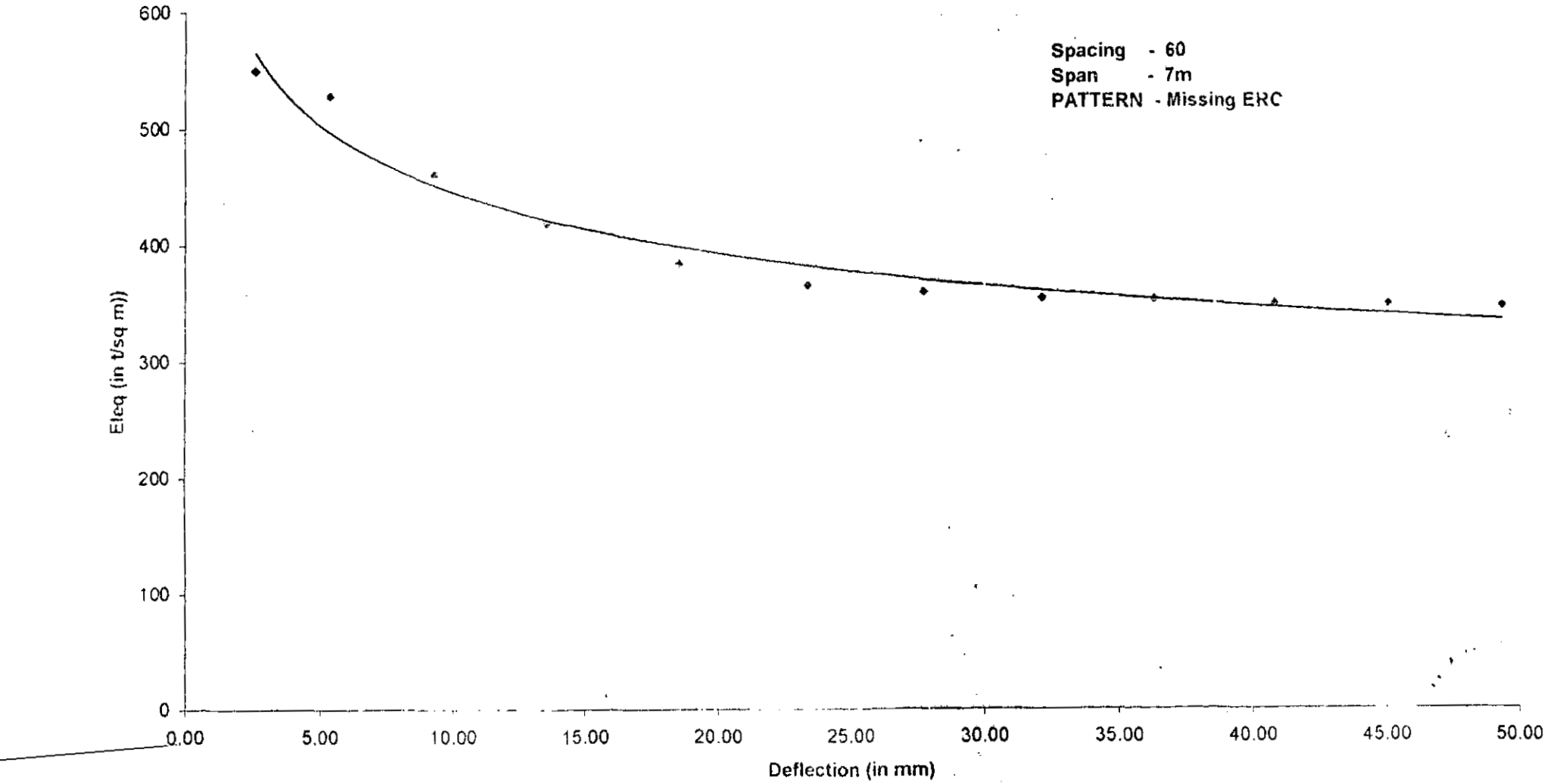
S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	2.60	2.58	2.59	552
2	400	5.42	5.40	5.41	528
3	600	9.37	9.25	9.31	461
4	800	13.80	13.50	13.65	419
5	1000	18.85	18.35	18.60	384
6	1200	23.75	23.15	23.45	366
7	1400	28.15	27.40	27.78	360
8	1600	32.65	31.78	32.22	355
9	1800	36.40	36.34	36.37	354
10	2000	41.55	40.26	40.91	349
11	2200	45.85	44.40	45.13	348
12	**2400**	**50.35**	**48.61**	**49.48**	**347**

Table 15 : Showing Load, measured deflections and calculated Eleq



Graph 15A : Load Vs Deflection

05153



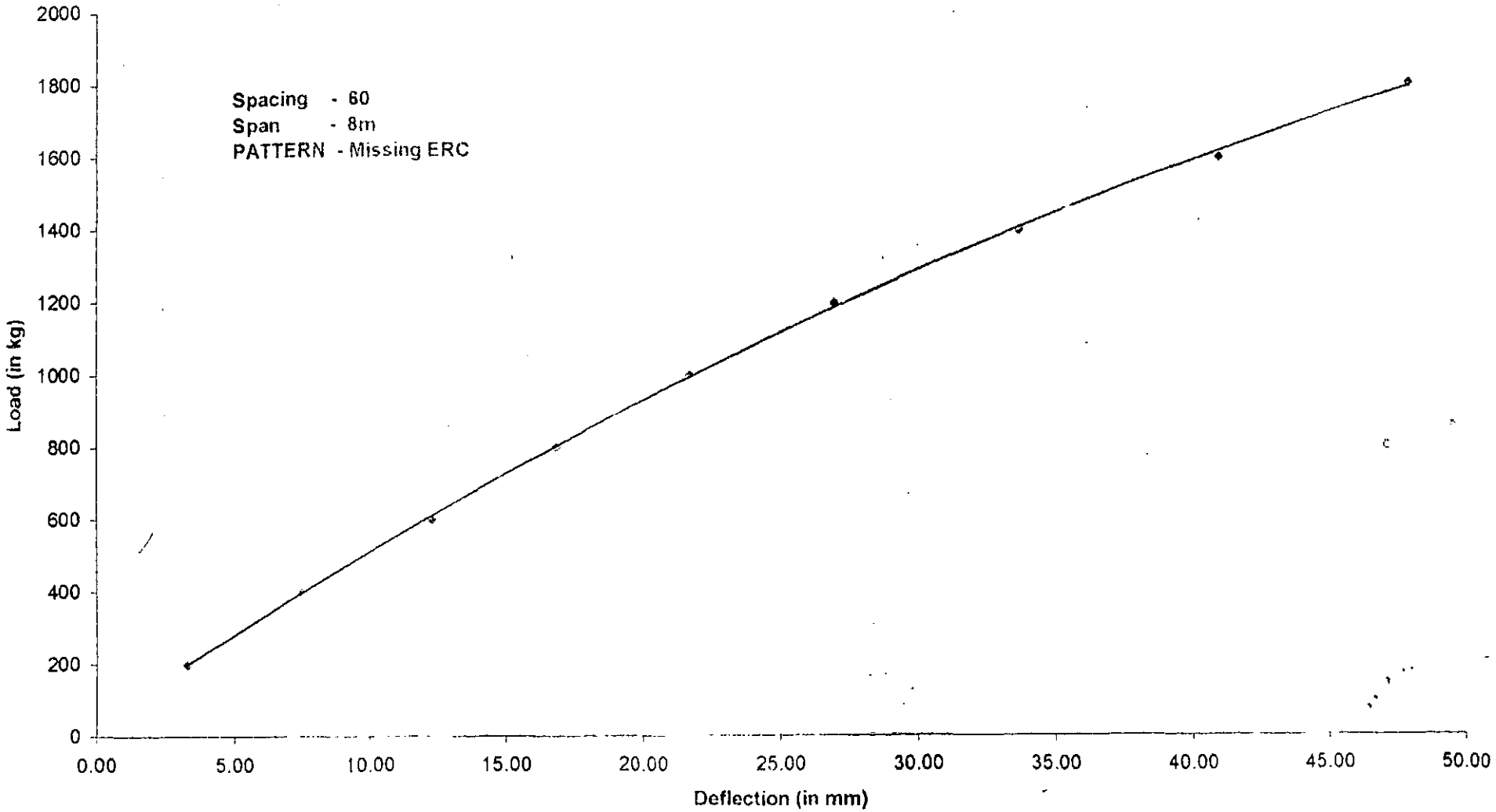
Graph 15B :Deflection Vs Eleq

05154

Spacing - 60cm
Span - 8m
Pattern - Missing ERC

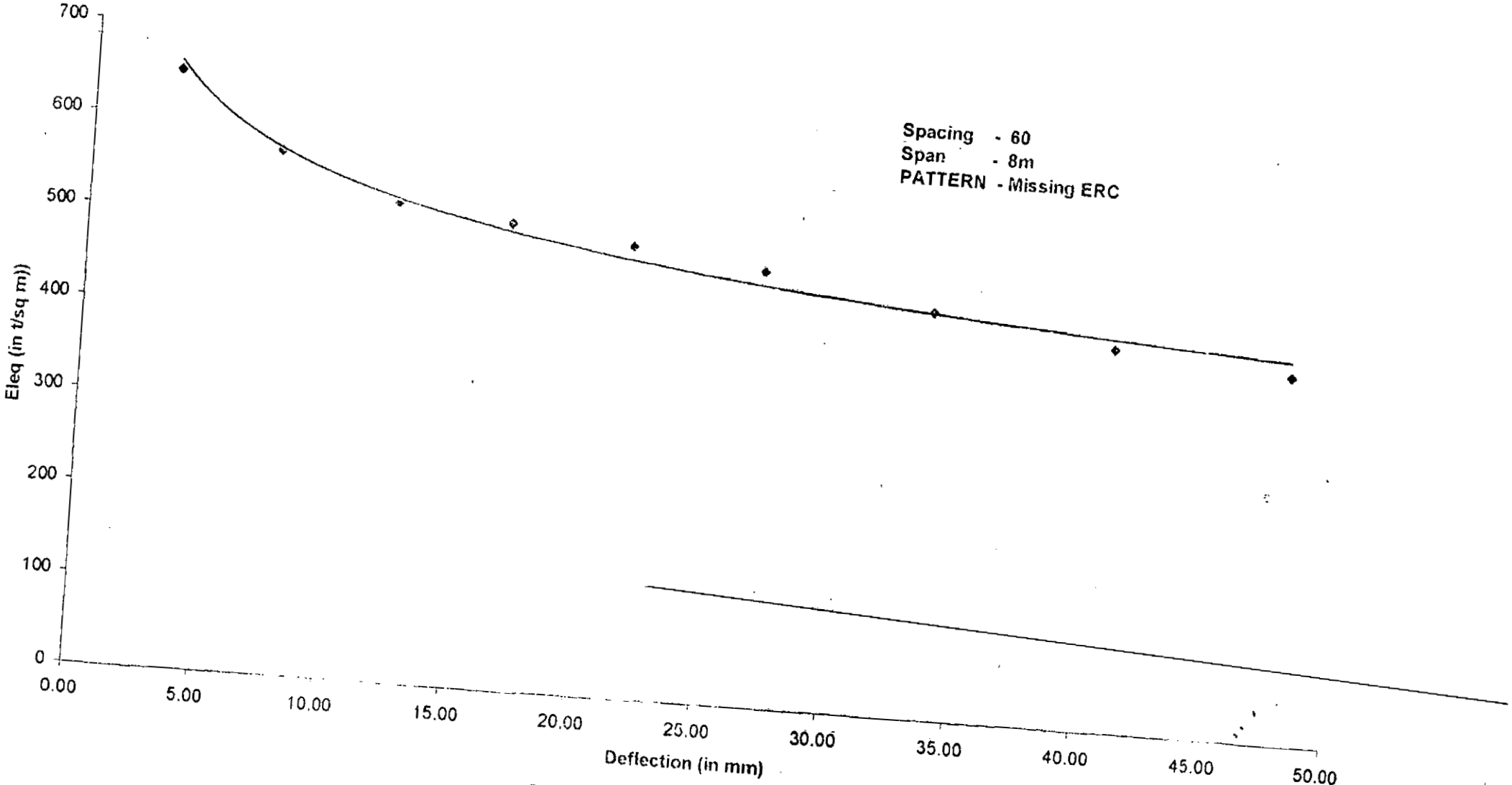
S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	3.30	3.28	3.29	648
2	400	7.55	7.45	7.50	569
3	600	12.45	12.15	12.30	520
4	800	17.05	16.65	16.85	506
5	1000	21.99	21.45	21.72	491
6	1200	27.32	26.65	26.99	474
7	1400	34.05	33.42	33.74	443
8	1600	41.30	40.70	41.00	416
9	**1800**	**48.50**	**47.60**	**48.05**	**400**

Table 16 : Showing Load, measured deflections and calculated Eleq



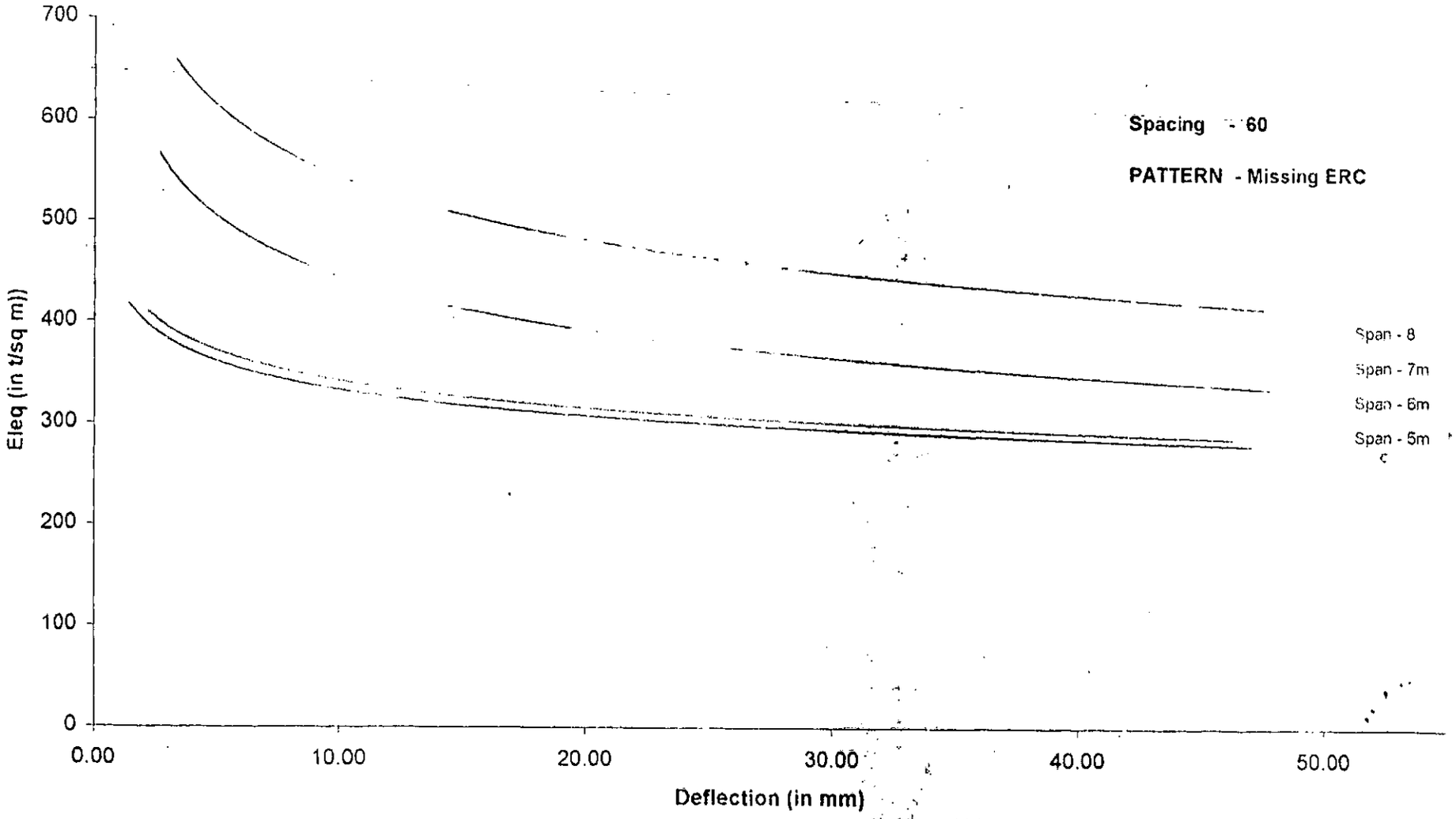
Graph 16A : Load Vs Deflection

05156



Graph 16B : Deflection Vs Eleq

05157



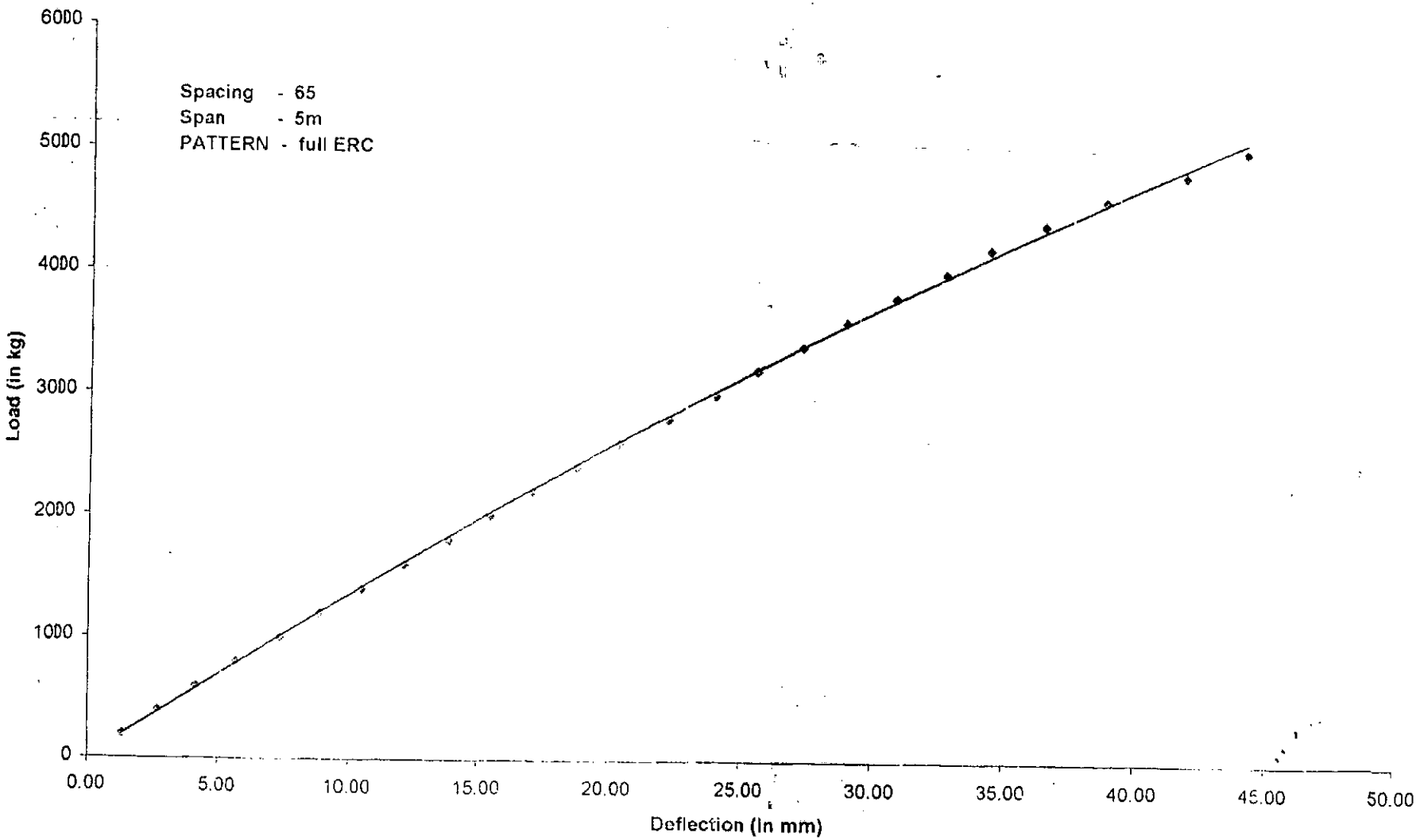
Graph : Combined Deflection Vs Eleq

05158

Spacing - 65cm
Span - 5m
Pattern - Full ERC

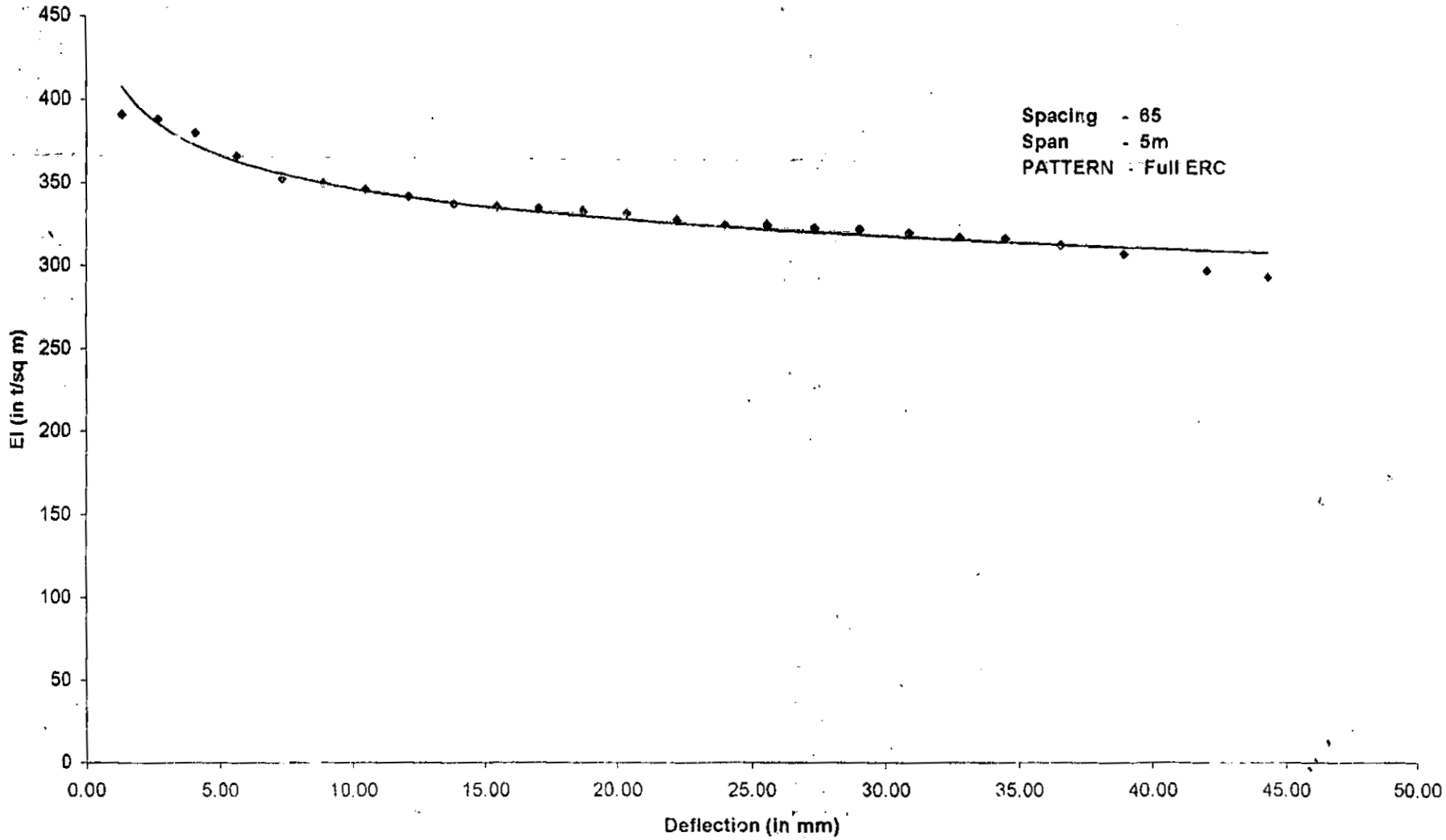
S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def(mm)	EI (t/sq m)
1	200	1.34	1.32	1.33	392
2	400	2.76	2.60	2.68	389
3	600	4.24	3.97	4.11	381
4	800	5.89	5.48	5.69	366
5	1000	7.61	7.15	7.38	353
6	1200	9.13	8.70	8.92	351
7	1400	10.75	10.30	10.53	346
8	1600	12.41	11.92	12.17	343
9	1800	14.10	13.67	13.89	338
10	2000	15.95	15.05	15.50	336
11	2200	17.58	16.60	17.09	335
12	2400	19.26	18.30	18.78	333
13	2600	20.98	19.82	20.40	332
14	2800	22.80	21.75	22.28	327
15	3000	24.60	23.55	24.08	325
16	3200	26.29	25.05	25.67	325
17	3400	28.31	26.55	27.43	323
18	3600	30.05	28.15	29.10	322
19	3800	32.15	29.78	30.97	320
20	4000	34.12	31.60	32.86	317
21	4200	35.94	33.20	34.57	316
22	4400	38.20	35.10	36.65	313
23	4600	40.71	37.29	39.00	307
24	4800	43.83	40.35	42.09	297
25	**5000**	**46.26**	**42.55**	**44.41**	**293**

Table 17 : Showing Load, measured deflections and calculated EI



Graph 17A : Load Vs Deflection

05160



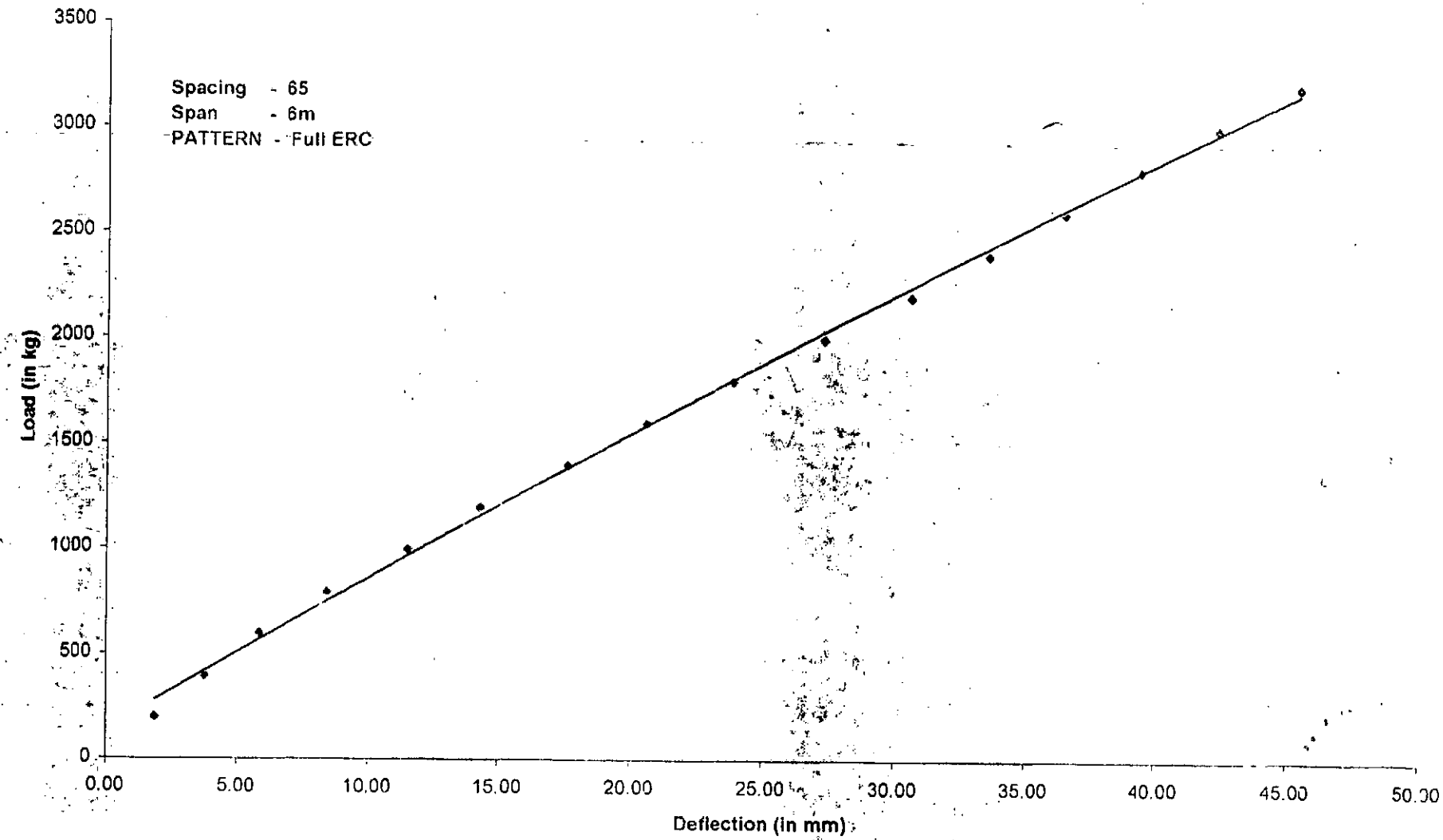
Graph 17B : Deflection Vs Eleq

05161

Spacing - 65cm
Span - 6m
Pattern - Full ERC

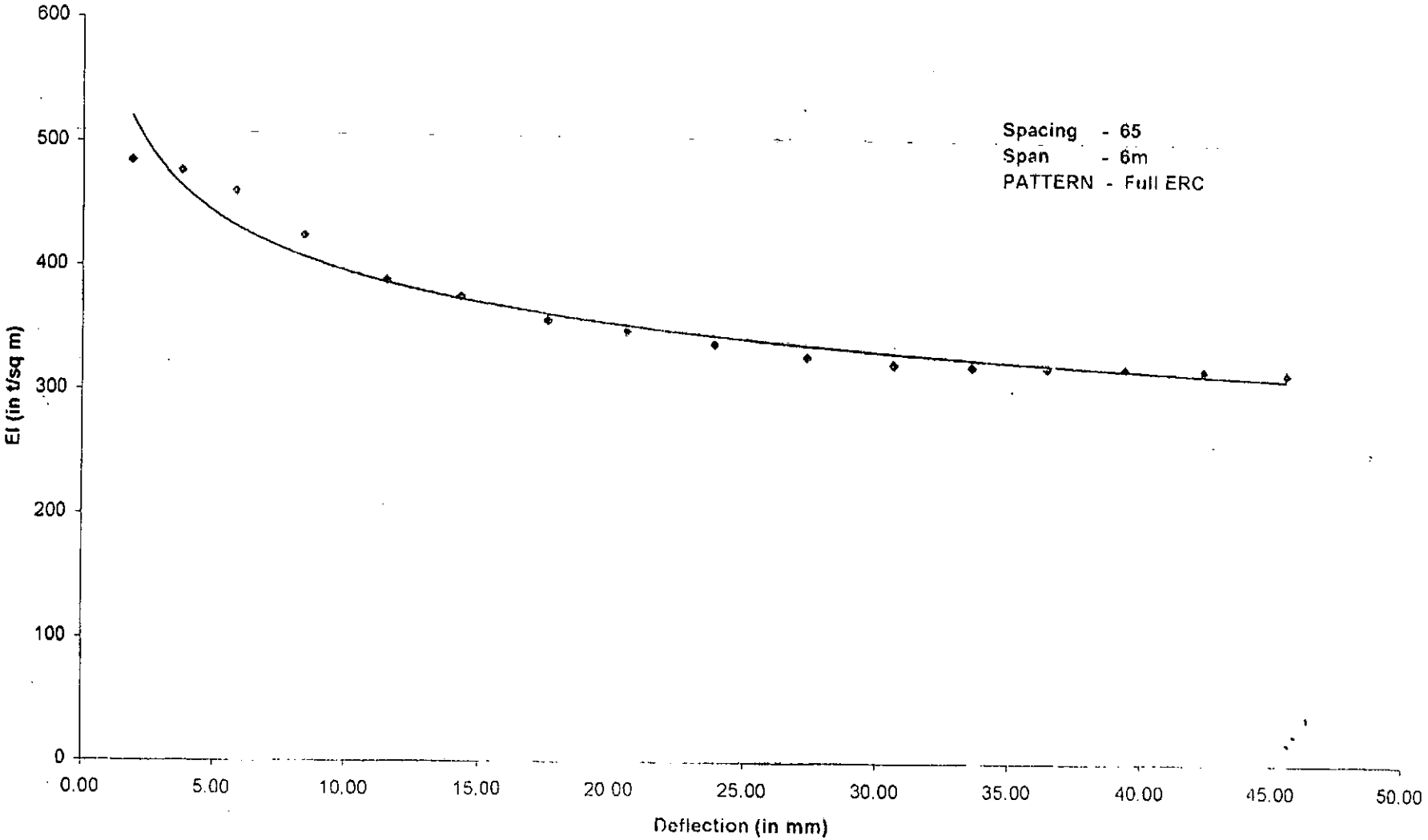
S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	EI (t/sq m)
1	200	1.86	1.85	1.86	485
2	400	3.80	3.75	3.78	477
3	600	6.42	5.30	5.86	461
4	800	9.08	7.84	8.46	426
5	1000	12.20	10.90	11.55	390
6	1200	15.05	13.65	14.35	376
7	1400	18.35	16.95	17.65	357
8	1600	21.33	19.90	20.64	349
9	1800	24.68	23.20	23.94	338
10	2000	28.24	26.60	27.42	328
11	2200	31.58	29.85	30.72	322
12	2400	34.42	32.93	33.68	321
13	2600	37.52	35.60	36.56	320
14	2800	40.52	38.4	39.46	319
15	3000	43.48	41.4	42.44	318
16	**3200**	**46.72**	**44.48**	**45.60**	316

Table 18 : Showing Load, measured deflections and calculated EI



Graph 18A : Load Vs Deflection

05163



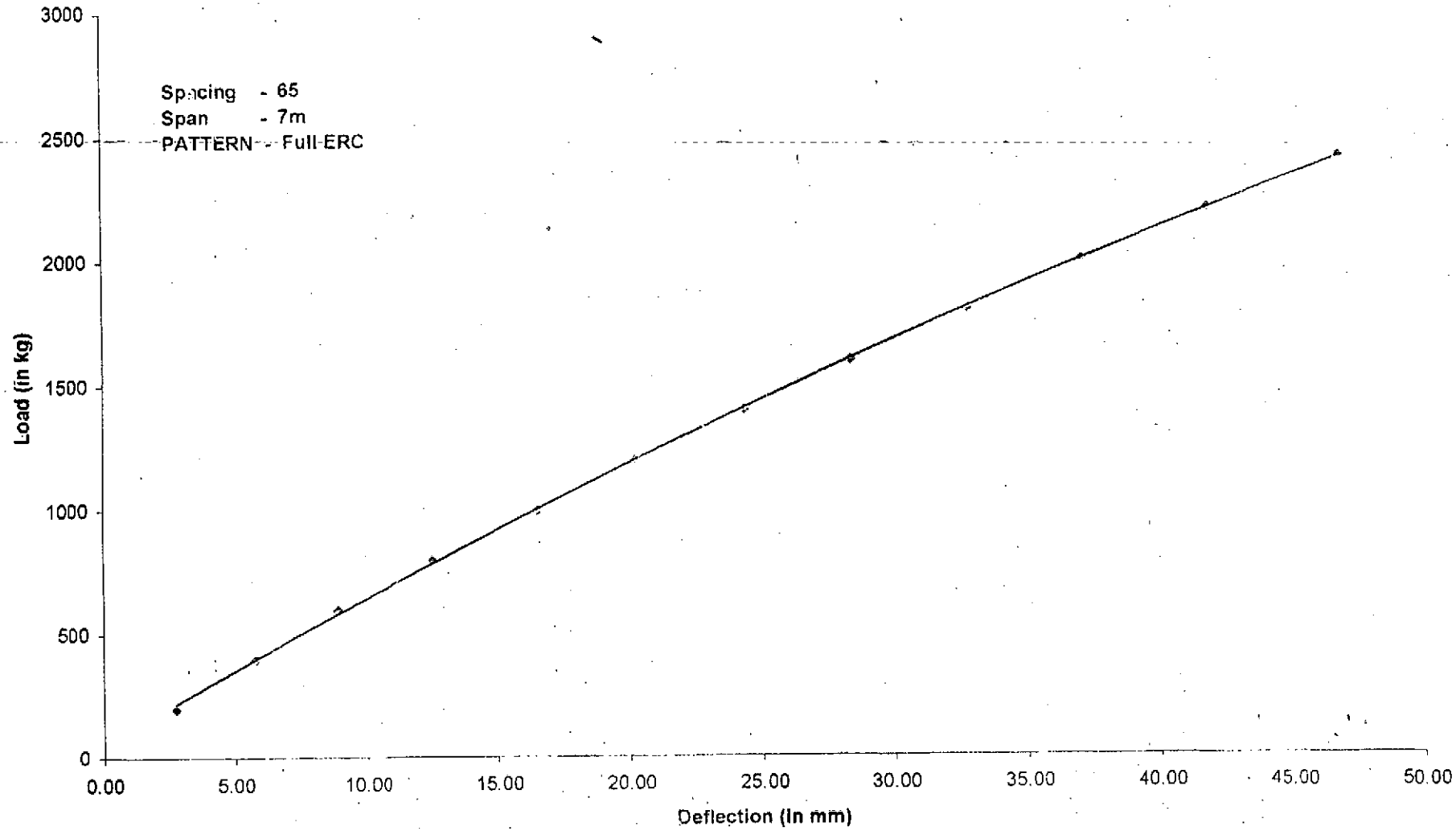
Graph 18B : **Deflection Vs Eleq**

05164

Spacing - 65cm
Span - 7m
Pattern - Full ERC

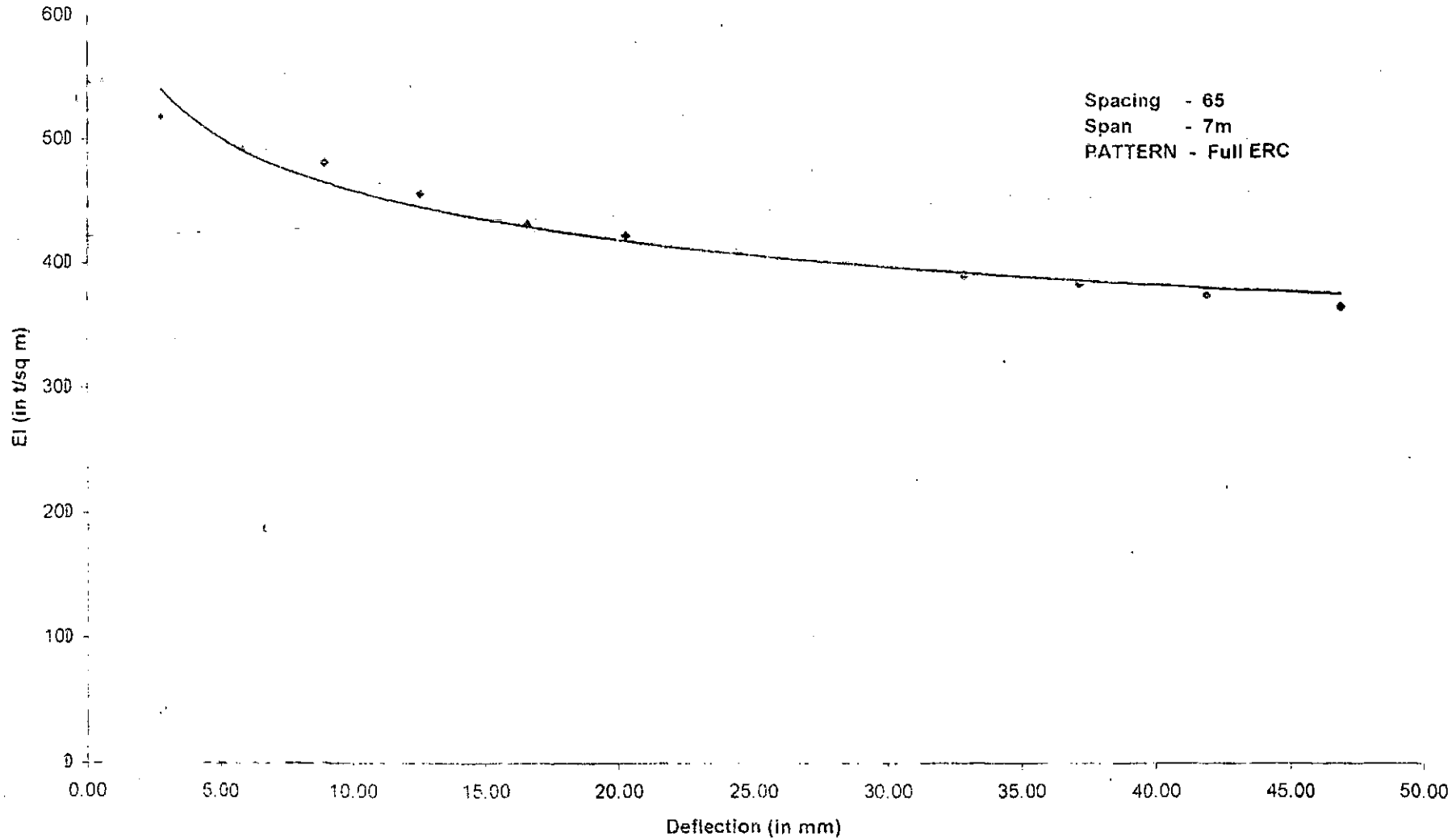
S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	EI (t/sq m)
1	200	2.76	2.74	2.75	520
2	400	5.86	5.71	5.79	494
3	600	9.05	8.75	8.90	482
4	800	12.65	12.40	12.53	456
5	1000	16.68	16.40	16.54	432
6	1200	20.55	19.95	20.25	423
7	1400	24.75	24.03	24.39	410
8	1600	28.95	27.90	28.43	402
9	1800	33.4	32.25	32.83	392
10	2000	37.85	36.45	37.15	385
11	2200	42.68	41.10	41.89	375
12	2400	47.75	46.05	46.90	366

Table 19 : Showing Load, measured deflections and calculated EI



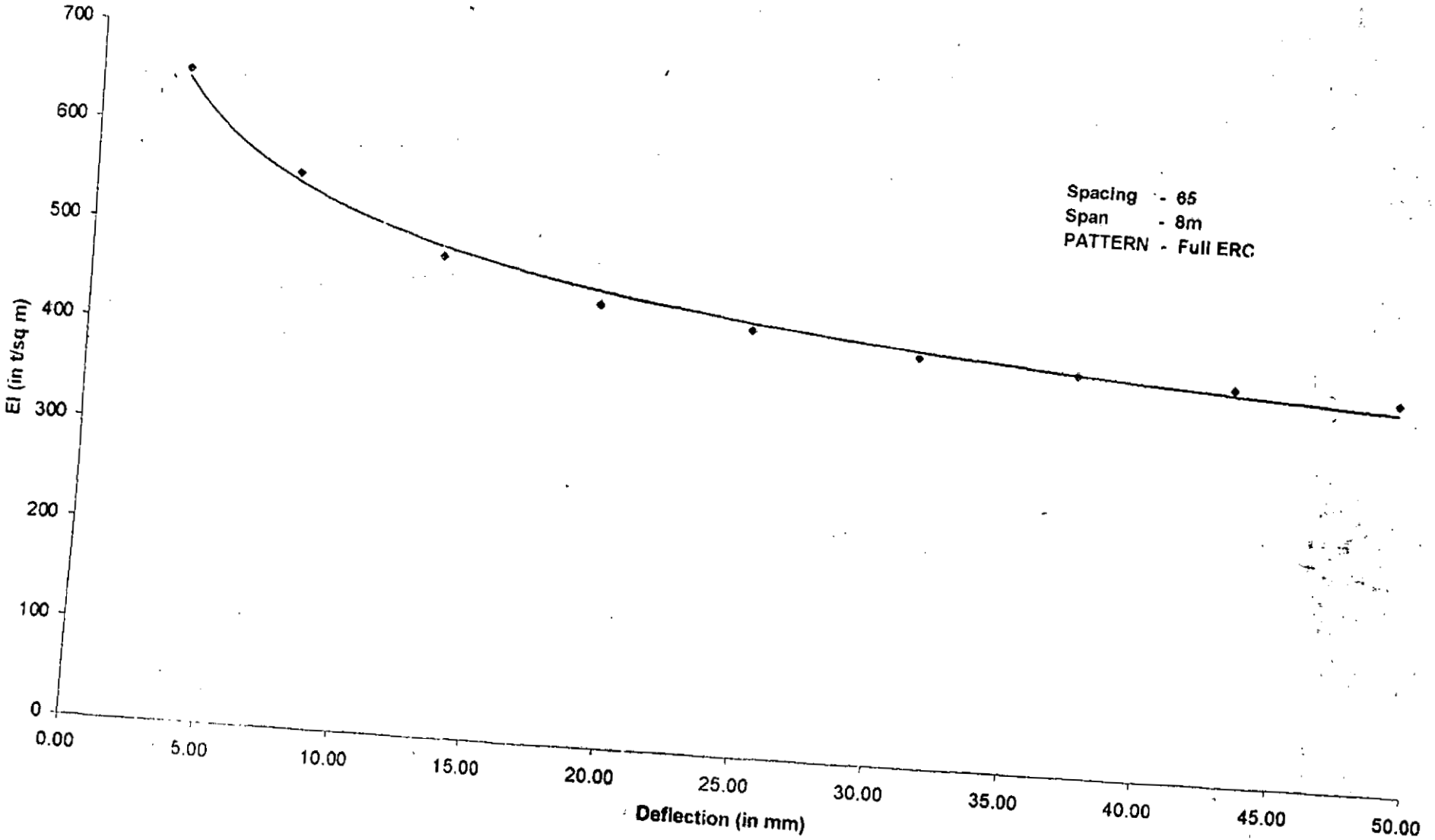
Graph 19A : **Load Vs Deflection**

05166



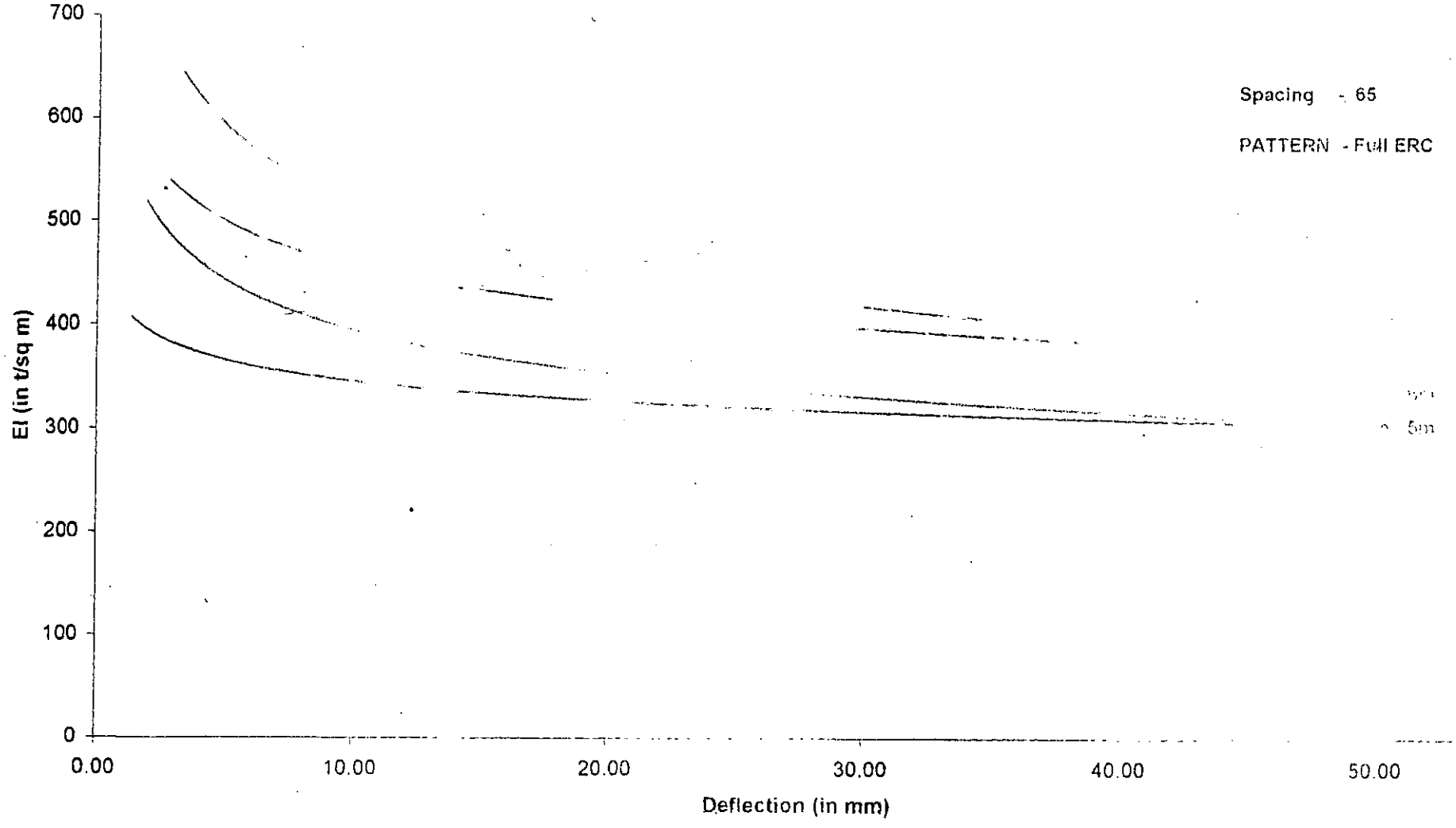
Graph 19B : Deflection Vs Eleq

05167



Graph 20B : Deflection Vs Eleq

05169



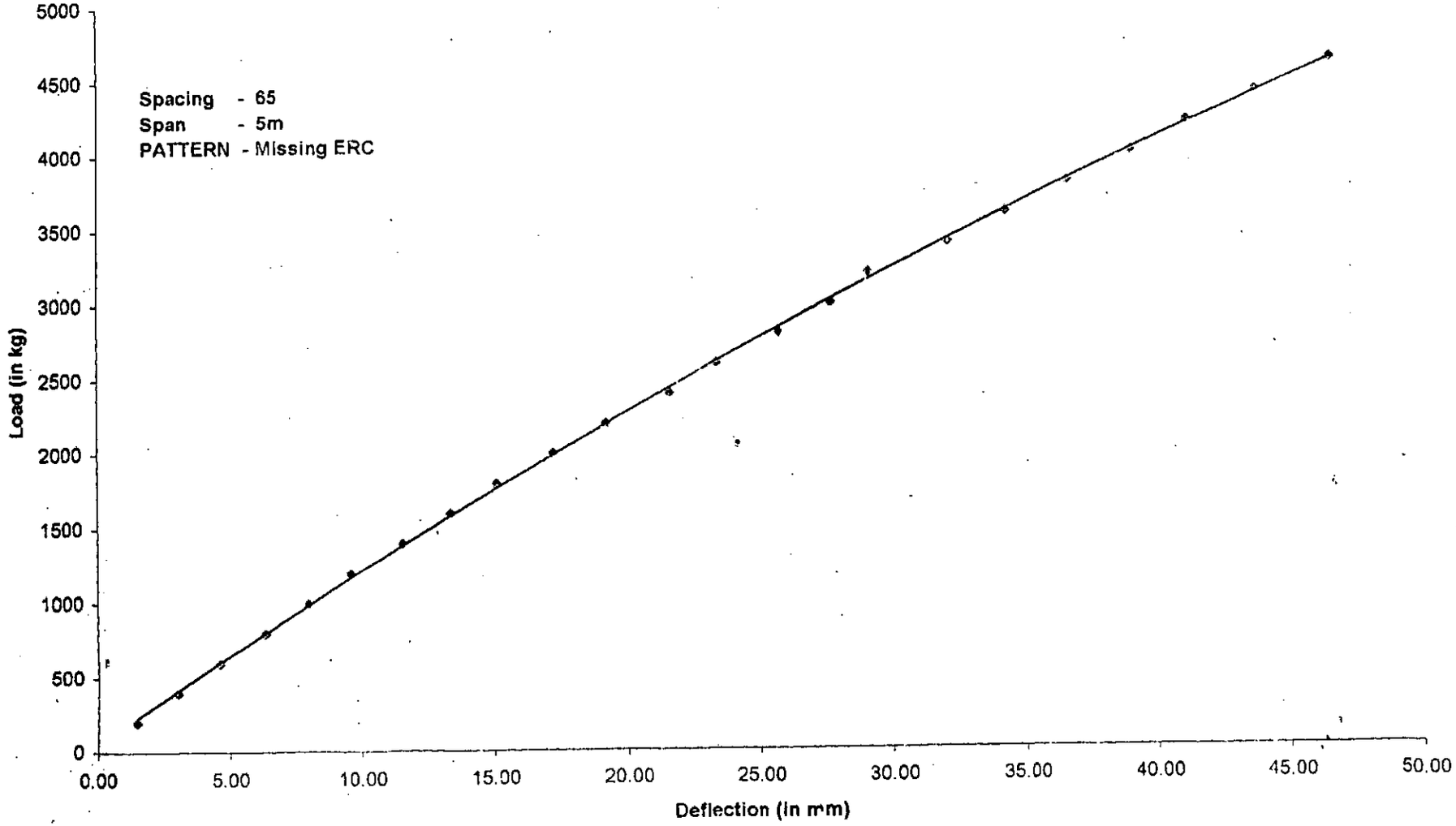
Graph : Combined Deflection Vs EI

05170

Spacing - 65cm
Span - 5m
Pattern - Missing ERC

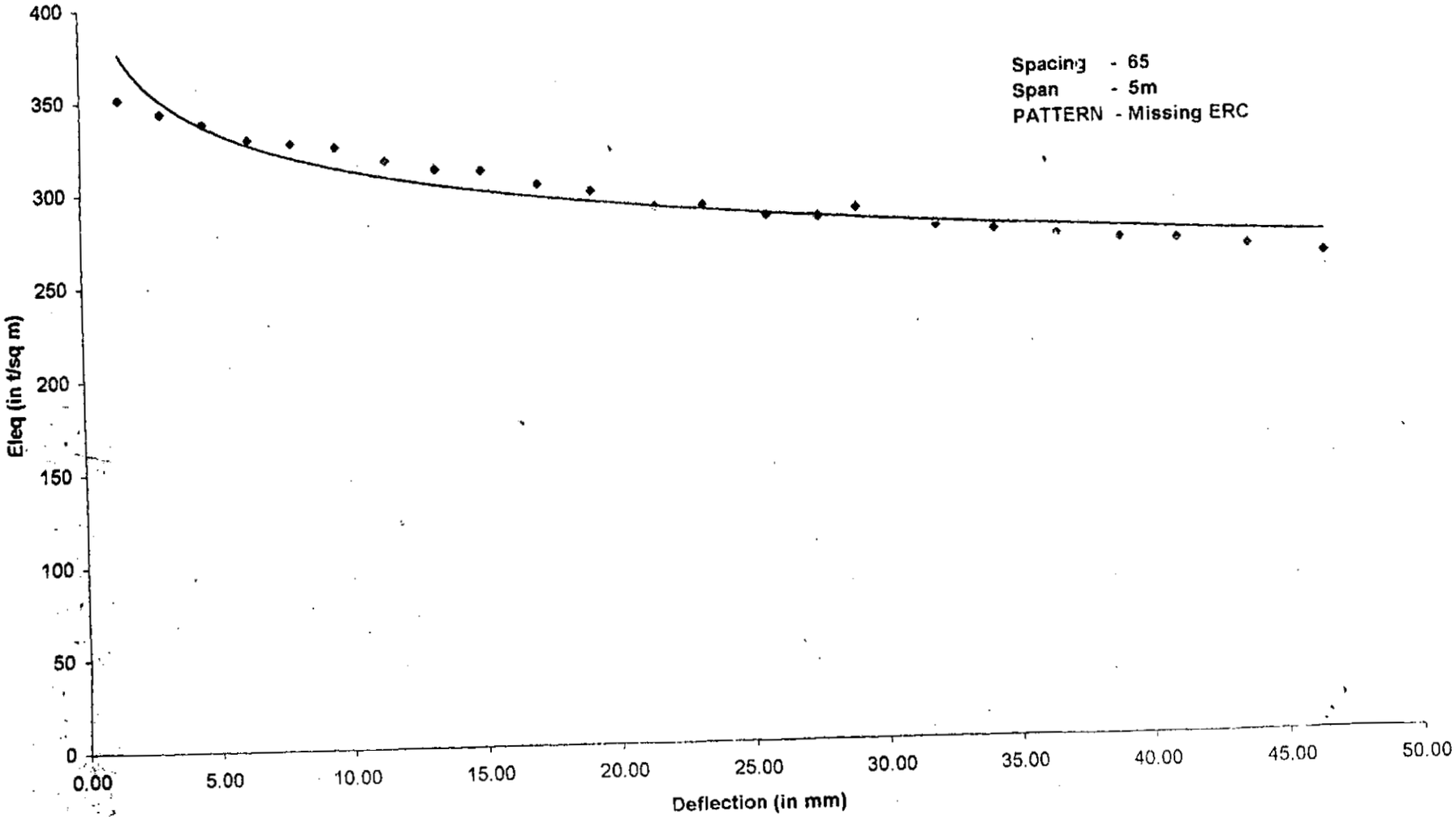
S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	1.49	1.47	1.48	352
2	400	3.07	2.99	3.03	344
3	600	4.75	4.50	4.63	338
4	800	6.50	6.15	6.33	329
5	1000	8.20	7.73	7.97	327
6	1200	10.05	9.20	9.63	325
7	1400	11.85	11.19	11.52	316
8	1600	13.80	12.95	13.38	312
9	1800	15.99	14.20	15.10	311
10	2000	18.20	16.25	17.23	302
11	2200	20.45	18.00	19.23	298
12	2400	22.55	20.70	21.63	289
13	2600	24.32	22.50	23.41	289
14	2800	26.80	24.77	25.79	283
15	3000	28.85	26.60	27.73	282
16	3200	30.02	28.25	29.14	286
17	3400	33.01	31.25	32.13	276
18	3600	35.25	33.40	34.33	273
19	3800	37.85	35.55	36.70	270
20	4000	40.25	37.95	39.10	266
21	4200	42.45	39.98	41.22	265
22	4400	45.15	42.50	43.83	261
23	**4600**	**47.85**	**45.45**	**46.65**	257

Table 21 : Showing Load, measured deflections and calculated Eleq



Graph 21A : Load Vs Deflection

05172

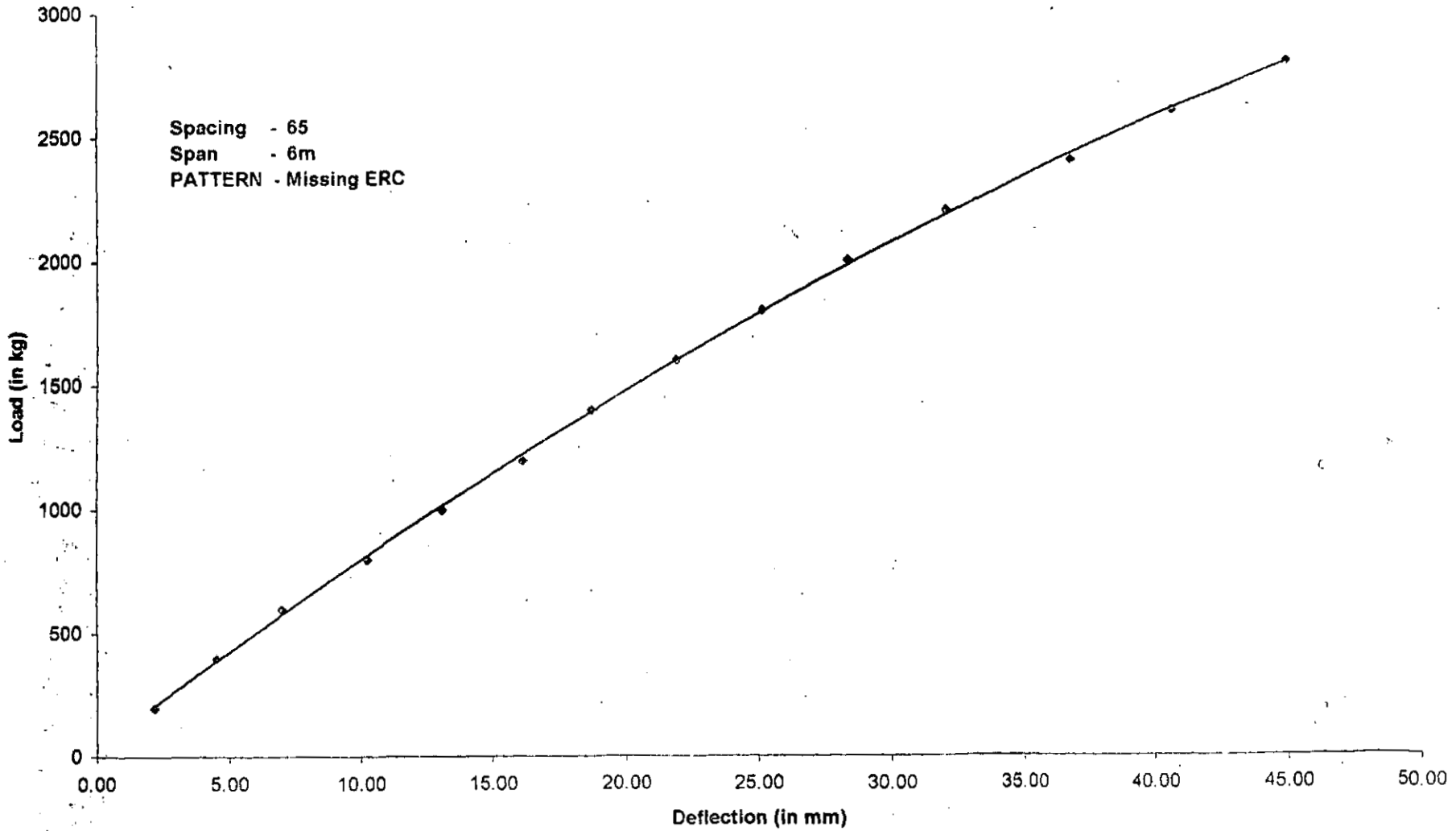


Graph 21B : Deflection Vs Eleq

Spacing - 65cm
Span - 6m
Pattern - Missing ERC

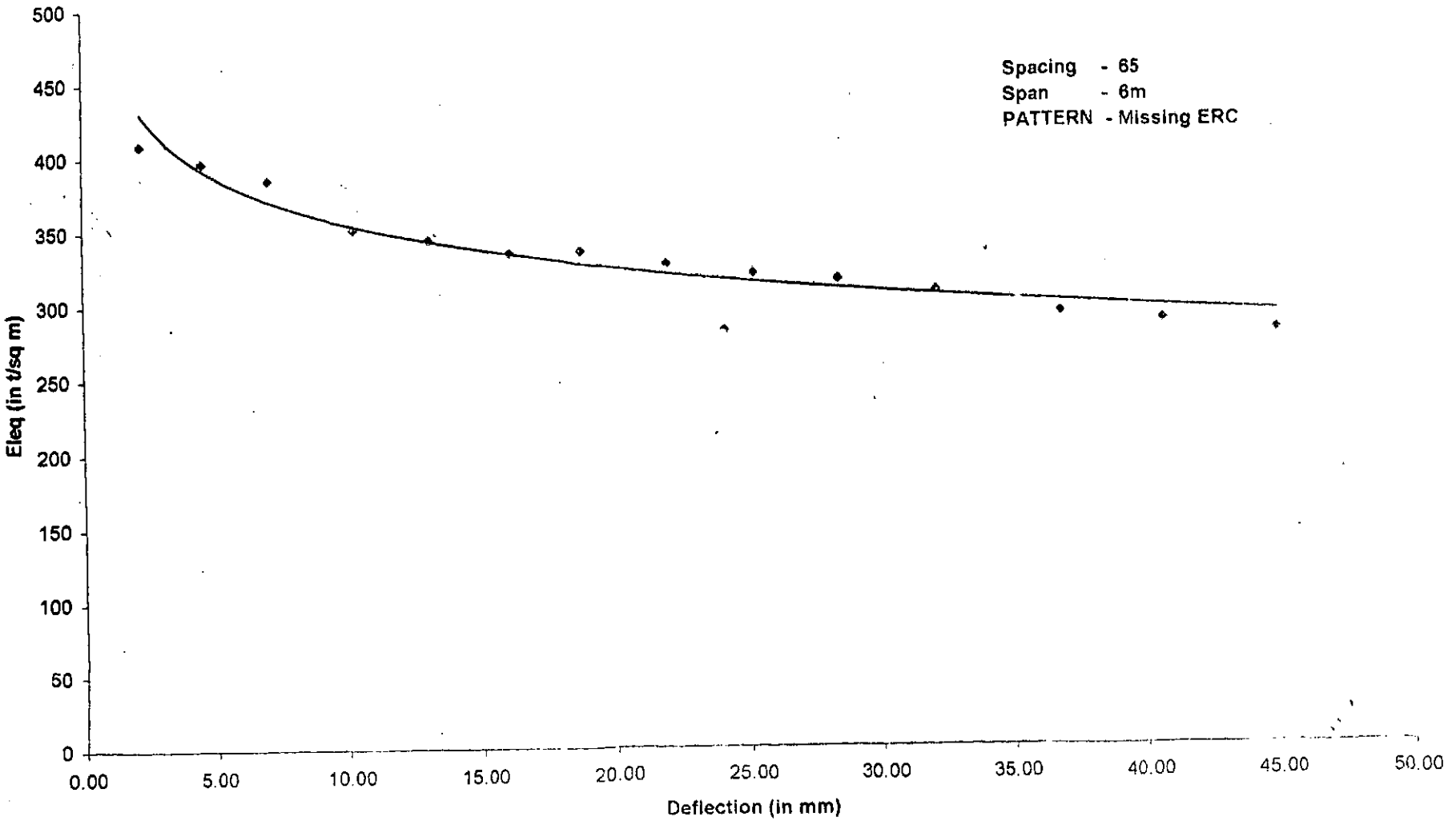
S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	2.22	2.18	2.20	409
2	400	4.60	4.45	4.53	398
3	600	7.15	6.85	7.00	386
4	800	10.45	10.02	10.24	352
5	1000	13.35	12.81	13.08	344
6	1200	16.40	15.85	16.13	335
7	1400	19.20	18.26	18.73	336
8	1600	22.50	21 44	21.97	328
9	1800	25.40	25.04	25.22	321
10	2000	28.75	28.12	28.44	317
11	2200	33.10	31.12	32.11	308
12	2400	37.50	36.19	36.85	293
13	2600	41.45	39.95	40.70	287
14	**2800**	**45.85**	**44.10**	**44.98**	**280**

Table 22 : Showing Load, measured deflections and calculated Eleq



Graph 22A : Load Vs Deflection

05175



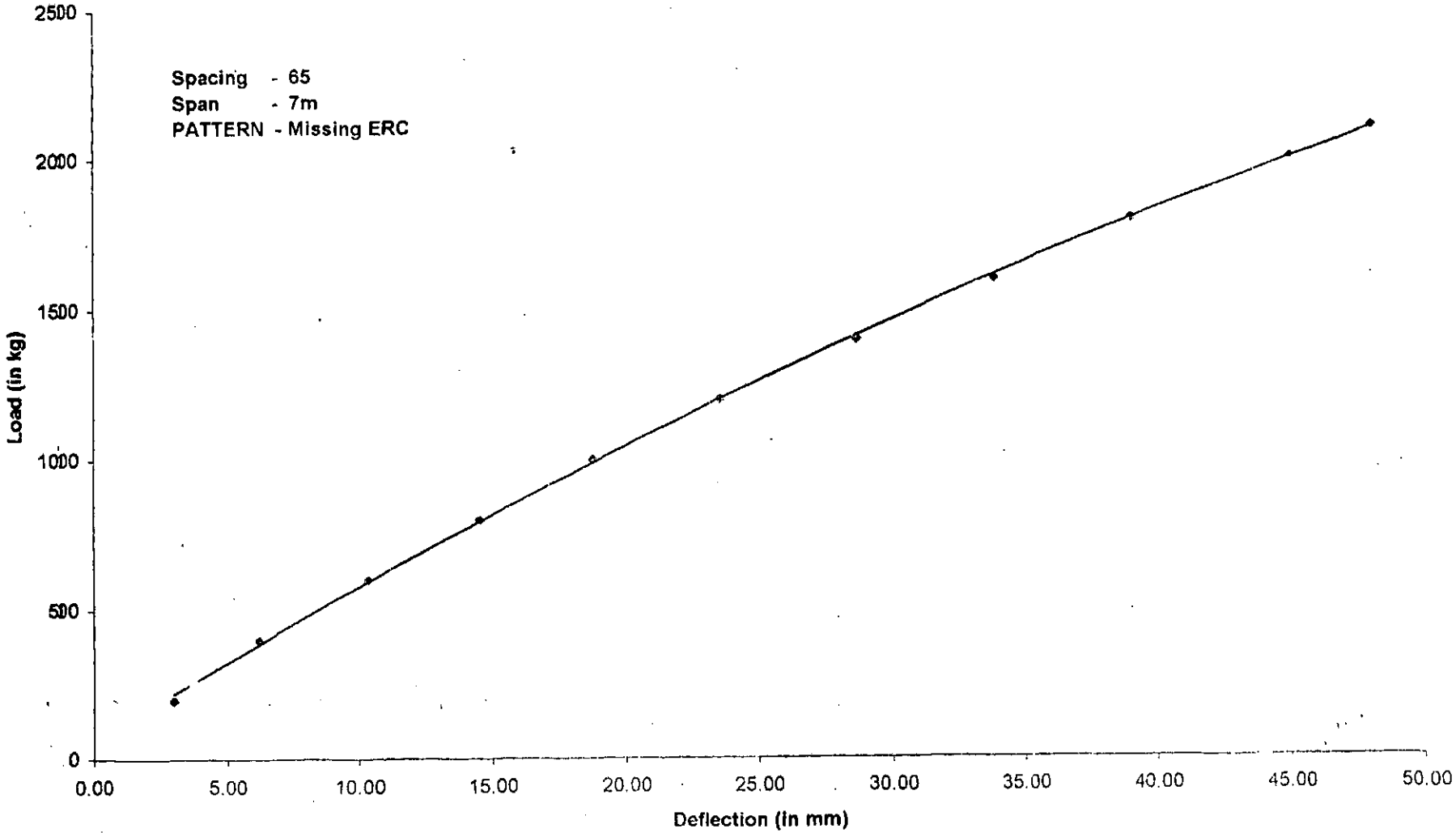
Graph 22B : Deflection Vs Eleq

05176

Spacing - 65cm
Span - 7m
Pattern - Missing ERC

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	3.02	3.00	3.01	475
2	400	6.30	6.09	6.20	461
3	600	10.55	10.15	10.35	414
4	800	14.85	14.19	14.52	394
5	1000	19.15	18.34	18.75	381
6	1200	24.15	23.05	23.60	363
7	1400	29.35	28.05	28.70	349
8	1600	34.25	33.60	33.93	337
9	1800	39.35	38.80	39.08	329
10	2000	45.40	44.60	45.00	318
11	**2100**	**48.55**	**47.65**	**48.10**	**312**

Table 23 : Showing Load, measured deflections and calculated Eleq



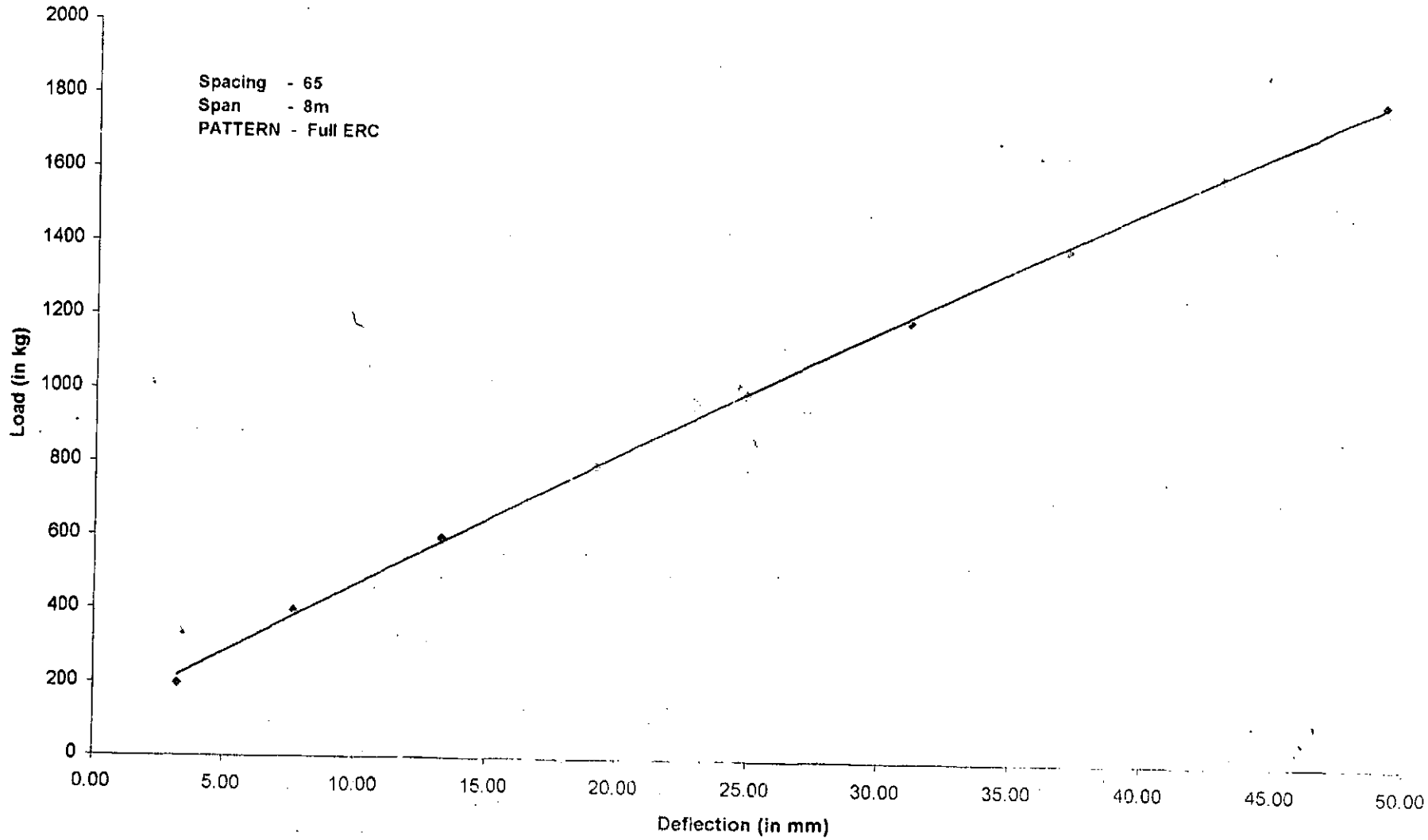
Graph 23A : Load Vs Deflection

05178

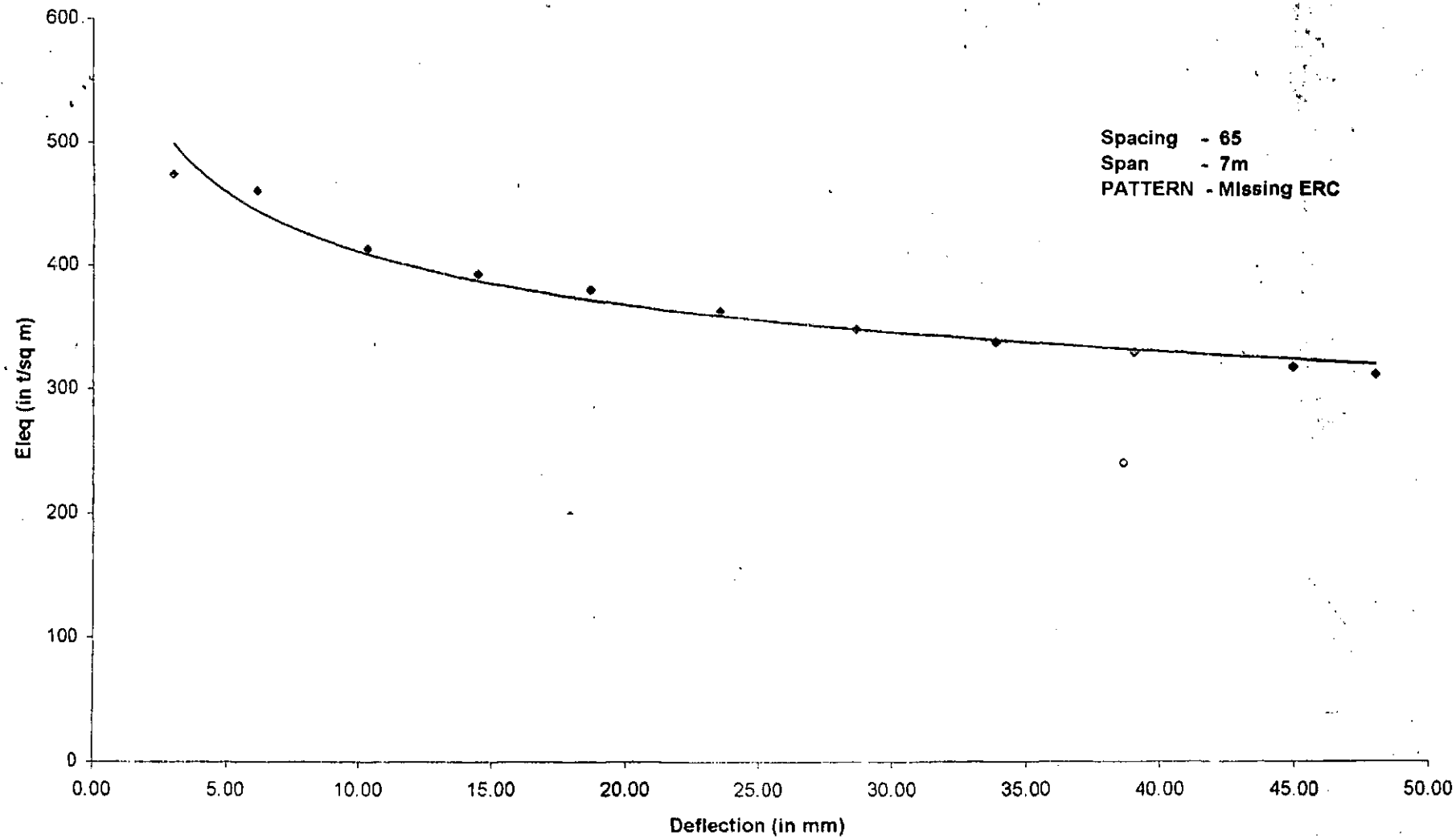
Spacing - 65cm
Span - 8m
Pattern - Full ERC

S.No.	Load (Kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	[illegible]
1	[illegible]	3.27	3.25	3.26	[illegible]
2	[illegible]	7.70	7.66	7.68	[illegible]
3	[illegible]	13.38	13.20	13.29	[illegible]
4	[illegible]	19.50	18.95	19.23	[illegible]
5	1000	25.40	24.45	24.93	[illegible]
6	1200	31.70	30.66	31.18	[illegible]
7	1400	37.85	36.45	37 15	402
8	[illegible]	43.90	42.15	43.03	397
9	**1800**	**50.10**	**48.20**	**49.15**	391

Table 20 : Showing Load, measured deflections and calculated EI



Graph 20A : **Load Vs Deflection**



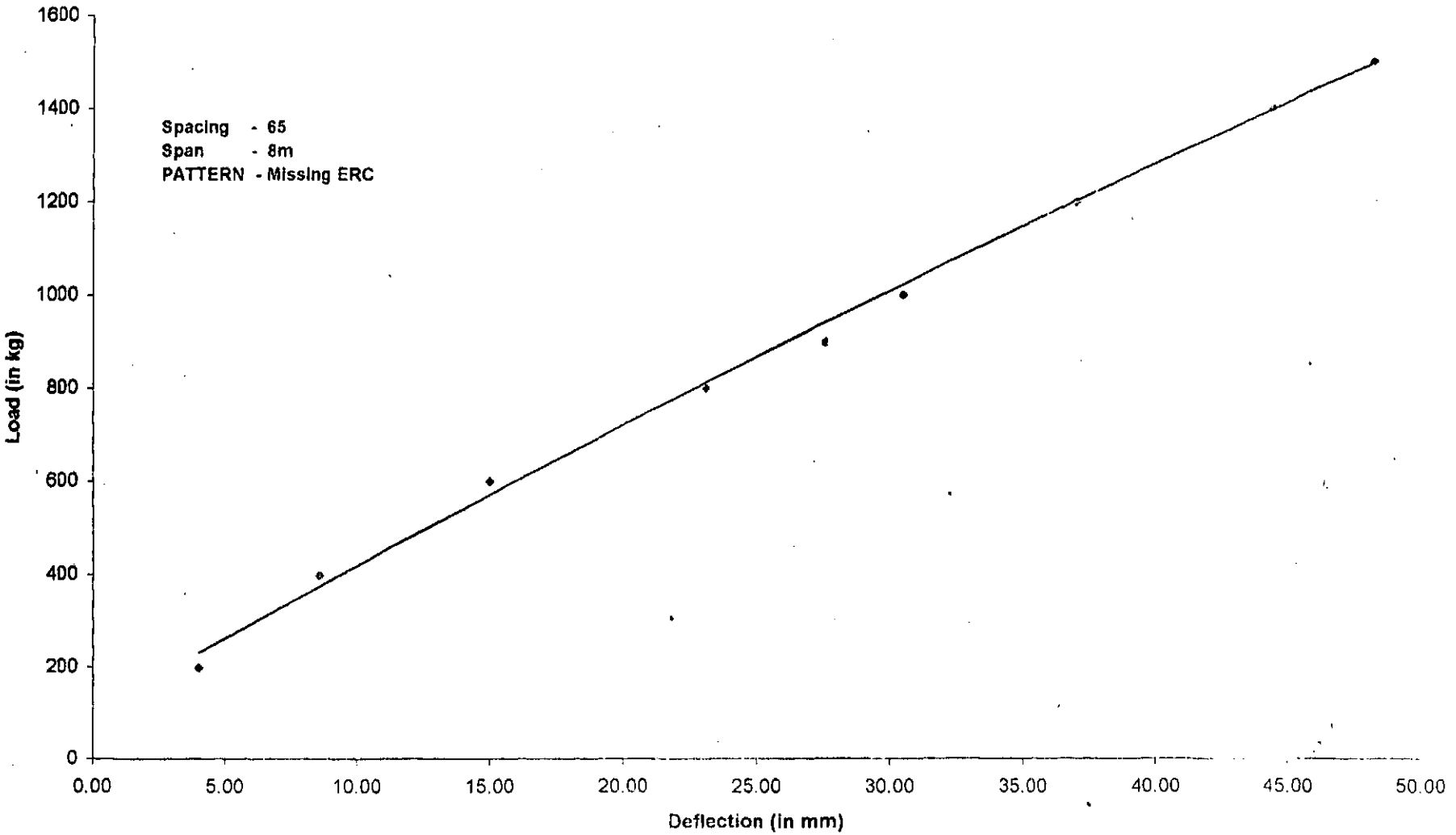
Graph 23B : Deflection Vs Eleq

05179

Spacing - 65cm
Span - 8m
Pattern - Missing ERC

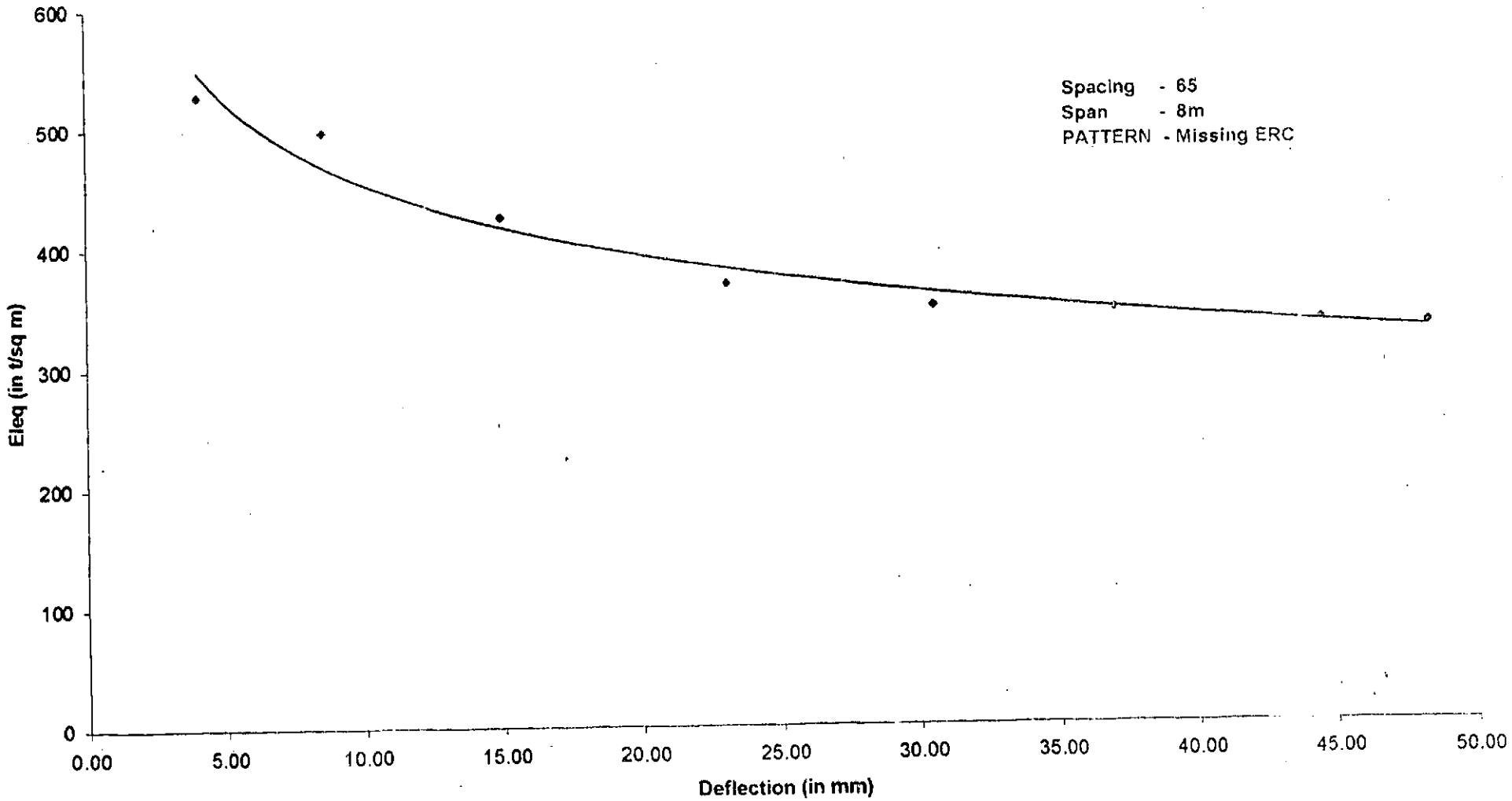
S.No.	Load (Kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	4.05	4.02	4.04	529
2	400	8.65	8.49	8.57	498
3	600	15.20	14.85	15.03	426
4	800	23.40	22.87	23.14	369
5	1000	30.95	30.19	30.57	349
6	1200	37.47	36.70	37.09	345
7	1400	45.20	43.88	44.54	335
8	**1500**	**49.60**	**47.15**	**48.38**	**331**

Table 24 : Showing Load, measured deflections and calculated Eleq



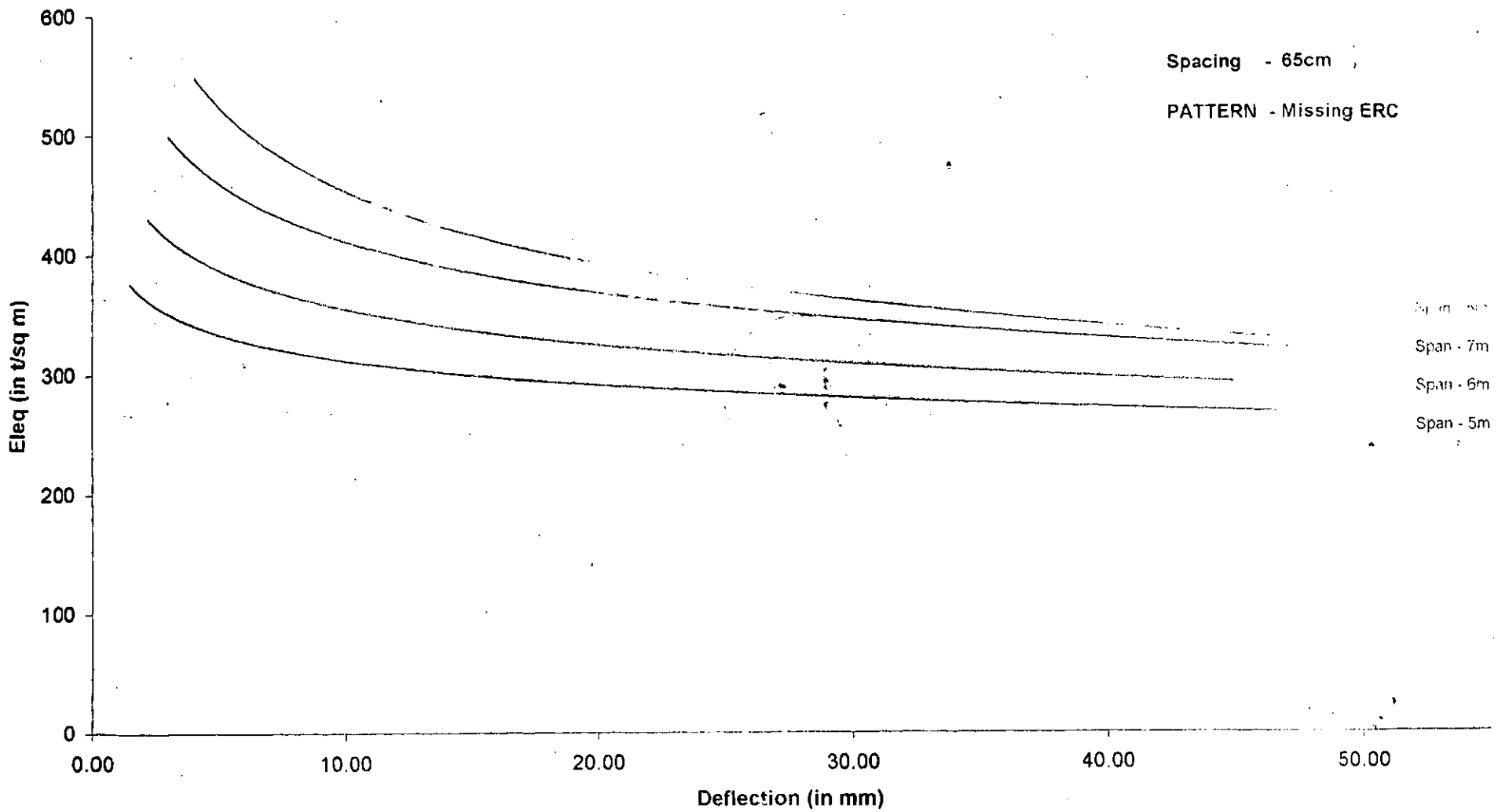
Graph 24A : Load Vs Deflection

05181



Graph 24B : Deflection Vs Eleq

05182



Graph : Combined Deflection Vs Eleq

05183