GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

FRAME RESISTANCE OF TRACK FRAME CONSISTING OF 52KG RAIL ON 60KG PSC SLEEPERS WITH ERC MK-III

REPORT NO. TM-120

MAY 2008

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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FRAME RESISTANCE OF TRACK FRAME CONSISTING OF 52KG 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 experimentally 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 52 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. forumalated 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. Details of 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) 52 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) 52 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) 52 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).

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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).

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 three locations as per photograph no.3 (i.e. foot of the rail, web of the rail & head of the rail) and electronic circuits were prepared to observe the stress at foot, web and head 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$\pm$0.2 ohms
. Gauge factor (24 °C,50%RH): 2.11$\pm$1.0%
. Adoptable thermal expansion: 11.7ppm/°c
. Transverse sensitivity (24 °C, 50%RH):0.20%
. Temperature coefficient of gauge factor: 0.8$\pm$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 of instruments :

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 6000kg available in TM Dte.. This proving ring was calibrated on dated 19-12-2006 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, web and head 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

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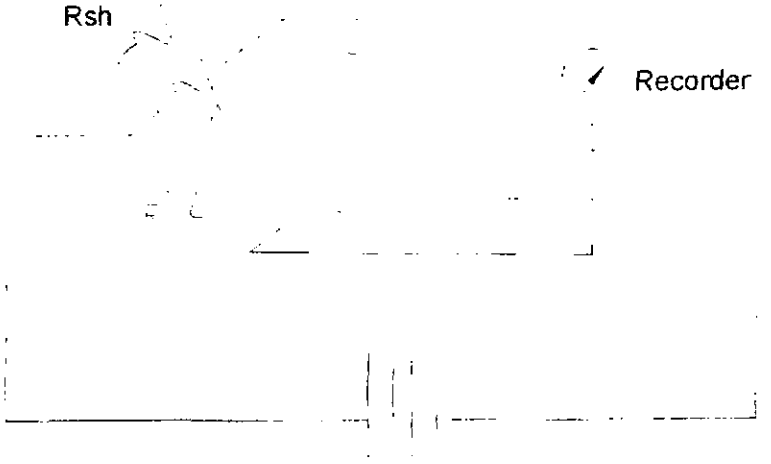
Stress = Rg x E/GF(Rg+Rsh) ----------Equation-2



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

5.Test Schedule:

Field trial were carried out in March-April,2008 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 52Kg(90UTS)
2. PSC Sleeper 60Kg (Drg. No. RDSO/T- 2496)
3. GRSP (RDSO/T-3711)
4. GFN liner (Drg. no. RDSO/T-3707&3708)
5. ERC Mk-III (RDSO/T-3701)
6. Hydraulic Jack 20T capacity
7. Proving Ring 6000Kg capacity
8. Dial Gauges (50 mm deflection , least count-0.01mm), Mitutoyo make
9. Astromed recorder
10. Strain gauges 10mm size, 120 Ω resistance

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7. Method of Analysis: Average deflection of both rail 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:

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 attaining 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 recorded load, measured deflections and calculated Eleq is annexed as graph 1 to 48 .Graph no. I,II,III,IV V,VI shows the comparison of load Vs Eleq on different spans on different sleeper spacings with full ERC pattern and missing ERCs on alternate sleeper pattern.

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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.

Table A: (Track Frame with full ERC)

Sleeper spacing	Span (met)	Load (kg)		Avg Def (mm)		Eleq (t/m²)	
		Min	Max	Min	Max	Max	Min
55 cm	5	206	5650	1021	48.39	444	304
	8	200	2200	2.78	43.78	769	536
60 cm	5	200	4600	1.4	48.3	372	248
	8	200	1800	3.06	47.62	697	403
65 cm	5	200	4200	1.6	47.34	326	231
	8	200	1600	3.55	49.14	601	347

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	4400	1.41	48.10	369	238
	8	200	1800	3.23	45.21	660	425
60 cm	5	200	4000	1.59	47.10	328	221
	8	200	1500	3.5	48.62	610	329
65 cm	5	200	3800	1.72	48.55	303	204
	8	200	1200	4.35	46.55	490	275

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Table C : Summry of load, measured deflection and calculated Eleq.

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	206	5650	1.21	48.39	444	304	200	4400	1.41	48.10	369	238
	6	200	3600	1.89	47.51	476	341	200	2800	2.03	45.35	443	278
	7	200	2600	2.24	47.84	639	388	200	2200	2.45	47.45	583	331
	8	200	2200	2.78	43.78	769	536	200	1800	3.23	45.21	660	425
60 cm	5	200	4600	1.40	48.30	372	248	200	4000	1.59	47.10	328	221
	6	200	3200	2.08	48.90	433	294	200	2600	2.27	45.15	396	259
	7	200	2400	2.90	48.17	493	356	200	2000	2.83	47.04	505	304
	8	200	1800	3.06	47.62	697	403	200	1500	3.50	48.62	610	329
65 cm	5	200	4200	1.60	47.34	326	231	200	3800	1.72	48.55	303	204
	6	200	2800	2.19	45.95	412	274	200	2400	2.45	45.55	367	237
	7	200	2200	3.04	47.43	470	331	200	1800	3.24	49.05	441	262
	8	200	1600	3.55	49.14	601	347	200	1200	4.35	46.55	490	275

* Proving ring of capacity 6000 kg has been used for trial accept one trial of 5m span of sleeper spacing of 55cm with full ERC pattern.
* 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 observed 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.**

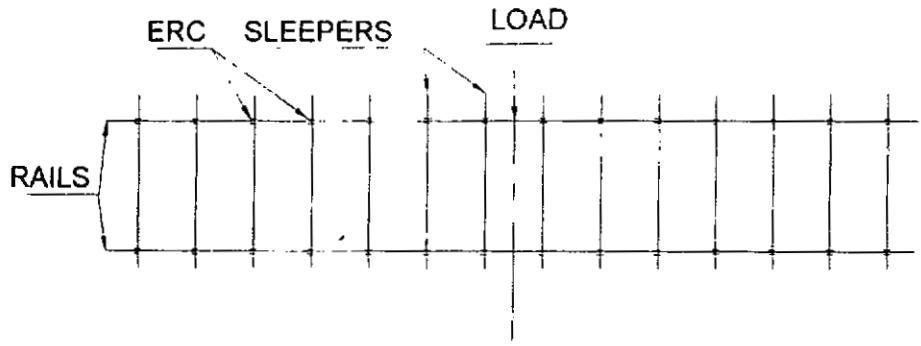


FIG. 1(a) : TRACK FRAME WITH FULL ERC

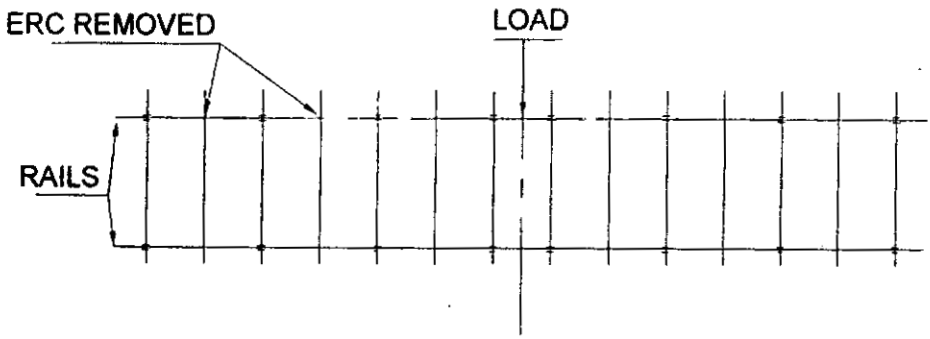
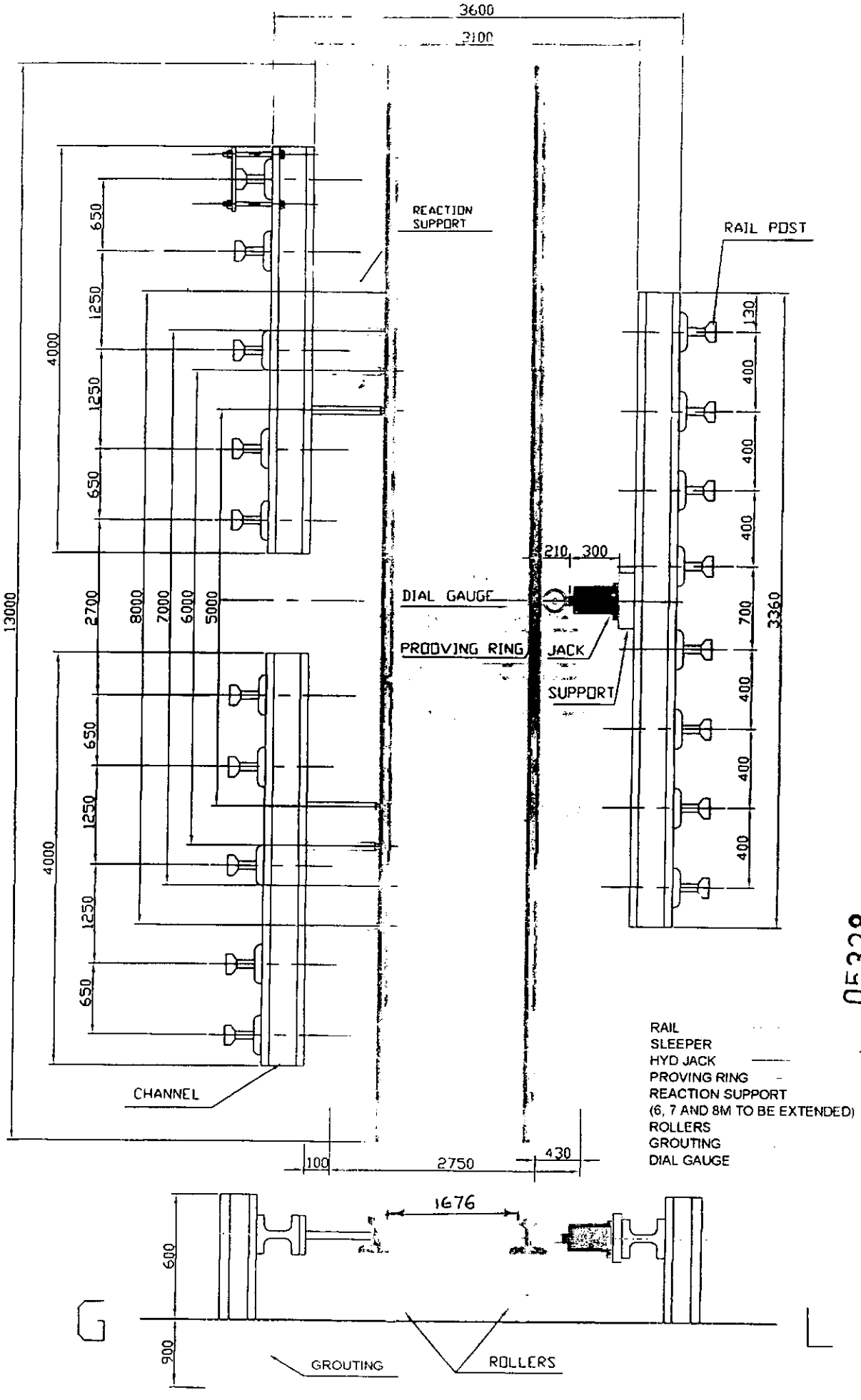


FIG. 1(b): TRACK FRAME WITH MISSING ERCs ON ALTERNATE SLEEPER



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TEST SETUP PLAN FOR FRAME RESISTANCE TRIALS

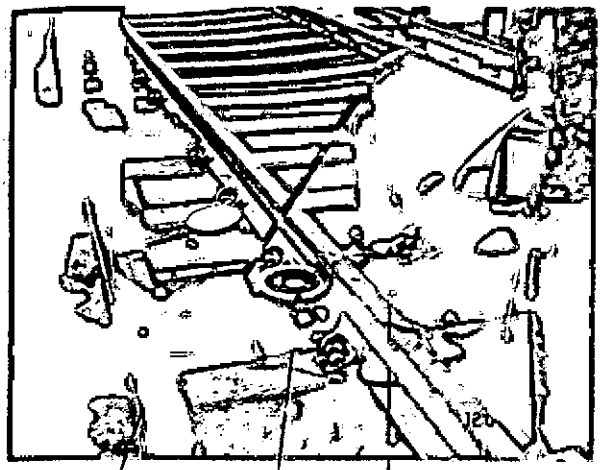

Photo:1

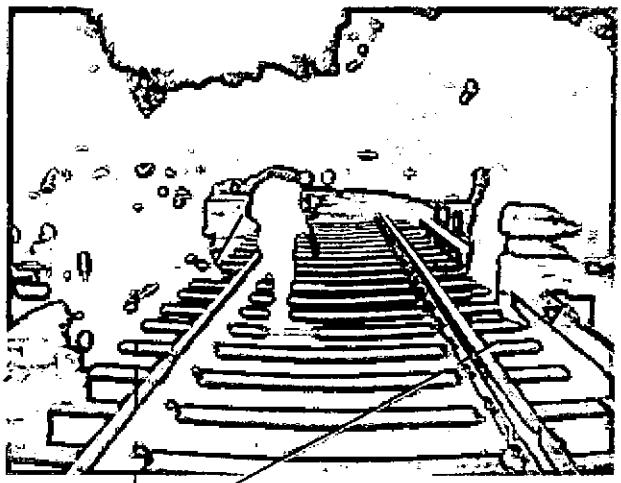

Photo:2

Photographs showing Track Frame assembly and loading set up

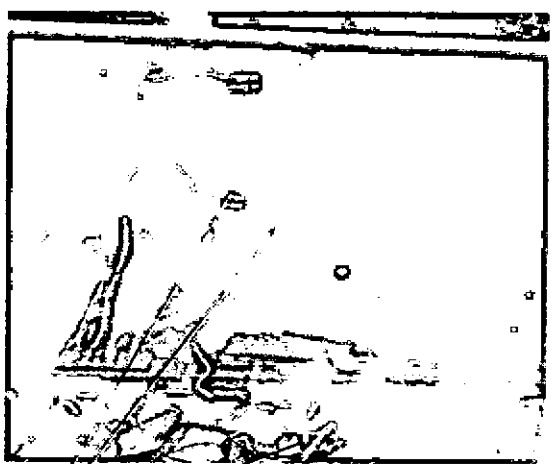

Photo:3

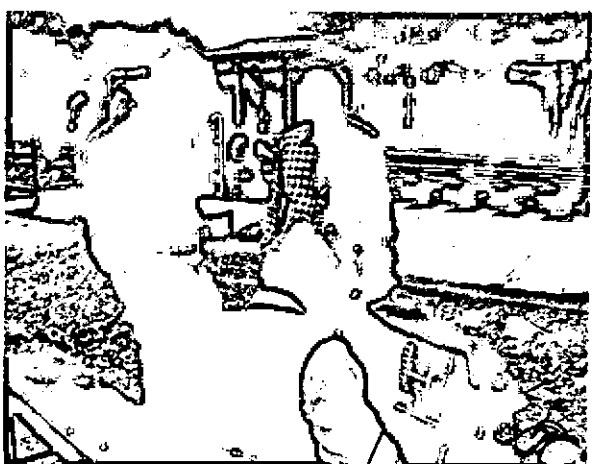

Photo:4

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

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Sleeper spacing - 55cm
Span - 5m
Pattern - Full ERC

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	206	1.23	1.19	1.21	444
2	397	2.52	2.44	2.48	[illegible]
3	602	3.89	3.80	3.85	408
4	793	5.28	5.08	5.18	399
5	998	6.75	6.52	6.64	392
6	1204	8.25	8.01	8.13	386
7	1394	9.78	9.51	9.65	[illegible]
8	1600	11.37	10.79	11.08	376
9	1805	12.88	12.26	12.57	374
10	1965	14.12	13.47	13.80	371
11	2245	16.29	15.57	15.93	367
12	2392	17.65	16.87	17.26	361
13	2539	18.68	18.06	18.47	358
14	2832	21.16	20.28	20.72	356
15	2979	22.42	21.54	21.98	353
16	3272	24.73	23.83	24.28	351
17	3419	26.05	25.13	25.59	348
18	3640	28.01	27.11	27.56	344
19	3859	30.01	28.99	29.50	341
20	4006	31.40	30.25	30.83	338
21	4152	32.80	31.60	32.20	336
22	4446	36.10	34.70	35.40	327
23	4592	37.70	35.88	36.79	325
24	4886	41.05	38.70	39.88	319
25	5032	42.70	40.19	41.45	316
26	5179	44.40	41.95	43.18	312
27	5472	47.80	45.32	46.56	306
28	5650	49.65	47.13	48.39	304

Table 1 : Showing Load, measured deflections and calculated Eleq

Sleeper spacing - 55cm
Span - 6m
Pattern - Full ERC

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	1.92	1.86	1.89	476
2	400	4.20	4.05	4.13	436
3	600	6.50	6.30	6.40	422
4	800	8.80	8.55	8.68	415
5	1000	11.25	10.85	11.05	407
6	1200	13.65	13.20	13.43	402
7	1400	16.10	15.80	15.95	395
8	1600	18.60	18.10	18.35	392
9	1800	21.00	20.40	20.70	391
10	2000	23.70	23.00	23.35	385
11	2200	26.20	25.50	25.85	383
12	2400	29.50	28.70	29.10	371
13	2600	32.50	31.70	32.10	364
14	2800	36.10	35.40	35.75	352
15	3000	39.05	38.05	38.55	350
16	3200	42.05	40.75	41.40	348
17	3400	45.00	44.10	44.55	343
18	3600	48.50	46.52	47.51	341

Table 2 : Showing Load, measured deflections and calculated Eleq

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

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	2.28	2.19	2.24	639
2	400	4.75	4.55	4.65	615
3	600	7.30	7.05	7.18	598
4	800	10.59	10.22	10.41	549
5	1000	14.15	13.75	13.95	512
6	1200	17.92	17.40	17.66	486
7	1400	21.46	21.70	21.58	464
8	1600	25.95	25.30	25.63	446
9	1800	29.55	29.00	29.28	439
10	2000	34.05	32.60	33.35	429
11	2200	38.20	36.60	37.40	420
12	2400	43.75	42.10	42.93	400
13	**2600**	**48.58**	**47.10**	**47.84**	**388**

Table 3 : Showing Load, measured deflections and calculated Eleq

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

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	2.80	2.75	2.78	769
2	400	5.85	5.70	5.78	739
3	600	9.10	8.80	8.95	715
4	800	12.45	12.00	12.23	698
5	1000	16.20	15.60	15.90	671
6	1200	20.48	19.68	20.08	637
7	1400	25.18	24.25	24.72	604
8	1600	29.85	28.80	29.33	582
9	1800	34.65	33.55	34.10	563
10	2000	39.35	38.2	38.775	550
11	**2200**	**44.35**	**43.20**	**43.78**	**536**

Table 4 : Showing Load, measured deflections and calculated Eleq

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Sleeper Spacing - 55cm
Span - 5m
Pattern - Missing ERCs

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	1.45	1.37	1.41	369
2	400	3.20	3.05	3.13	333
3	600	5.20	4.83	5.02	312
4	800	7.40	6.85	7.13	292
5	1000	9.38	8.66	9.02	289
6	1200	11.74	10.80	11.27	277
7	1400	14.01	12.82	13.42	272
8	1600	16.15	14.70	15.43	270
9	1800	18.30	16.65	17.48	268
10	2000	20.00	19.10	19.55	266
11	2200	22.30	21.25	21.78	263
12	2400	24.45	23.35	23.90	262
13	2600	27.10	25.90	26.50	256
14	2800	29.75	28.00	28.88	253
15	3000	31.98	30.05	31.02	252
16	3200	34.45	32.35	33.40	250
17	3400	36.95	34.80	35.88	247
18	3600	39.25	37.05	38.15	246
19	3800	41.84	39.50	40.67	243
20	4000	44.58	42.18	43.38	240
21	4200	46.95	44.50	45.73	239
22	**4400**	**49.35**	**46.85**	**48.10**	**238**

Table 5 : Showing Load, measured deflections and calculated Eleq

Sleeper Spacing - 55cm
Span - 6m
Pattern - Missing ERCs

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	2.05	2.01	2.03	443
2	400	5.15	5.02	5.09	354
3	600	8.10	7.88	7.99	338
4	800	11.12	10.90	11.01	327
5	1000	14.20	13.80	14.00	321
6	1200	17.35	16.85	17.10	316
7	1400	20.42	19.90	20.16	313
8	1600	23.65	23.05	23.35	308
9	1800	26.95	26.15	26.55	305
10	2000	30.25	29.15	29.70	303
11	2200	34.25	32.95	33.60	295
12	2400	37.85	36.40	37.13	291
13	2600	41.50	39.90	40.70	287
14	**2800**	**46.20**	**44.50**	**45.35**	**278**

Table 6 : Showing Load, measured deflections and calculated Eleq

Sleeper Spacing - 55cm
Span - 7m
Pattern - Missing ERCs

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	2.50	2.40	2.45	583
2	400	5.75	5.55	5.65	506
3	600	9.50	9.12	9.31	461
4	800	14.15	13.50	13.83	414
5	1000	18.18	17.97	18.08	395
6	1200	22.65	22.05	22.35	384
7	1400	27.05	26.10	26.58	376
8	1600	31.55	30.45	31.00	369
9	1800	36.50	35.20	35.85	359
10	2000	41.60	40.90	41.25	346
11	**2200**	**48.20**	**46.70**	**47.45**	**331**

Table 7 : Showing Load, measured deflections and calculated Eleq

Sleeper Spacing - 55cm
Span - 8m
Pattern - Missing ERCs

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	3.25	3.20	3.23	661
2	400	7.25	7.15	7.20	593
3	600	12.15	11.75	11.95	536
4	800	16.55	16.05	16.30	524
5	1000	21.35	20.55	20.95	509
6	1200	26.22	25.10	25.66	499
7	1400	32.05	30.35	31.20	479
8	1600	39.40	37.60	38.50	443
9	**1800**	**46.18**	**44.23**	**45.21**	**425**

Table 8 : Showing Load, measured deflections and calculated Eleq

05333

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

S.No.	Load (Kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	1.43	1.37	1.40	372
2	400	3.10	3.01	3.06	341
3	600	4.95	4.82	4.89	320
4	800	6.81	6.58	6.70	311
5	1000	8.90	8.45	8.68	300
6	1200	10.95	10.35	10.65	293
7	1400	12.95	12.25	12.60	289
8	1600	14.95	14.15	14.55	286
9	1800	16.85	16.15	16.50	284
10	2000	19.07	18.10	18.59	280
11	2200	21.20	20.12	20.66	277
12	2400	23.38	22.25	22.82	274
13	2600	25.76	23.90	24.83	273
14	2800	27.90	26.00	26.95	271
15	3000	29.95	27.85	28.90	270
16	3200	32.10	29.90	31.00	269
17	3400	34.38	32.02	33.20	267
18	3600	37.05	34.65	35.85	262
19	3800	39.52	37.00	38.26	259
20	4000	42.05	39.45	40.75	256
21	4200	44.55	41.77	43.16	253
22	4400	46.85	43.95	45.40	252
23	**4600**	**49.75**	**46.75**	**48.3**	**248**

Table 9 : Showing Load, measured deflections and calculated Eleq

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

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	2.10	2.06	2.08	433
2	400	4.70	4.40	4.55	396
3	600	7.50	7.15	7.33	369
4	800	10.28	9.75	10.02	359
5	1000	13.14	12.60	12.87	350
6	1200	16.20	15.49	15.85	341
7	1400	19.35	18.40	18.88	334
8	1600	22.45	21.45	21.95	328
9	1800	25.75	24.55	25.15	322
10	2000	29.35	27.65	28.50	316
11	2200	32.40	30.95	31.68	313
12	2400	36.30	34.90	35.60	303
13	2600	39.80	38.35	39.08	299
14	2800	43.3	41.85	42.58	296
15	3000	46.6	45.05	45.83	295
16	**3200**	**49.7**	**48.1**	48.90	**294**

Table 10 : Showing Load, measured deflections and calculated Eleq

05334

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

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	2.92	2.88	2.90	493
2	400	6.56	6.50	6.53	438
3	600	10.11	10.01	10.06	426
4	800	13.70	13.52	13.61	420
5	1000	17.55	17.32	17.44	410
6	1200	21.90	21.61	21.76	394
7	1400	26.55	26.16	26.36	380
8	1600	30.56	30.10	30.33	377
9	1800	34.01	34.58	34.30	375
10	2000	39.40	38.85	39.13	365
11	2200	44.02	43.32	43.67	360
12	**2400**	**48.52**	**47.82**	**48.17**	**356**

Table 11 : Showing Load, measured deflections and calculated Eleq

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

S.No.	Load (Kg)	Def 1(mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	3.11	3.00	3.06	698
2	400	7.48	7.22	7.35	580
3	600	11.65	11.32	11.49	557
4	800	16.75	16.25	16.50	517
5	1000	22.15	21.50	21.83	489
6	1200	27.80	26.90	27.35	468
7	1400	34.25	33.15	33.70	443
8	1600	40.40	39.45	39.93	427
9	1800	**48.25**	**47.18**	**47.72**	**402**

05335

Table 12 : Showing Load, measured deflections and calculated Eleq

Sleeper 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	1.62	1.55	1.59	329
2	400	3.50	3.45	3.48	300
3	600	5.35	5.24	5.30	295
4	800	7.65	6.62	7.14	292
5	1000	9.15	8.90	9.03	289
6	1200	11.30	10.95	11.13	281
7	1400	13.28	12.86	13.07	279
8	1600	15.39	15.00	15.20	274
9	1800	17.82	17.40	17.61	266
10	2000	20.40	19.86	20.13	259
11	2200	22.70	22.05	22.38	256
12	2400	24.92	24.10	24.51	255
13	2600	27.34	26.45	26.90	252
14	2800	29.95	28.95	29.45	248
15	3000	32.15	31.02	31.59	247
16	3200	34.43	33.25	33.84	246
17	3400	37.00	35.84	36.42	243
18	3600	41.04	39.55	40.30	233
19	3800	44.60	42.85	43.73	226
20	**4000**	**48.05**	**46.15**	**47.10**	**221**

Table 13 : Showing Load, measured deflections and calculated Eleq

Sleeper 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	2.28	2.25	2.27	397
2	400	4.96	4.82	4.89	368
3	600	8.28	8.12	8.20	329
4	800	11.42	11.19	11.31	318
5	1000	14.42	14.15	14.29	315
6	1200	17.48	17.25	17.37	311
7	1400	21.12	20.80	20.96	301
8	1600	24.74	24.35	24.55	293
9	1800	28.45	28.05	28.25	287
10	2000	32.58	32.09	32.34	278
11	2200	37.05	36.29	36.67	270
12	2400	41.30	40.50	40.90	264
13	**2600**	**45.55**	**44.75**	**45.15**	**259**

Table 14 : Showing Load, measured deflections and calculated Eleq

05335

Sleeper 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	2.85	2.81	2.83	505
2	400	6.50	6.35	6.43	445
3	600	11.04	10.80	10.92	393
4	800	16.10	15.64	15.87	360
5	1000	20.55	20.25	20.40	350
6	1200	25.78	25.36	25.57	335
7	1400	31.20	30.80	31.00	323
8	1600	36.75	36.20	36.48	313
9	1800	41.82	41.35	41.59	309
10	**2000**	**47.32**	**46.75**	**47.04**	**304**

Table 15 : Showing Load, measured deflections and calculated Eleq

Sleeper 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	3.52	3.47	3.50	610
2	400	8.84	8.70	8.77	487
3	600	14.85	14.62	14.74	434
4	800	20.05	20.69	20.37	419
5	1000	27.75	27.32	27.54	387
6	1200	35.75	35.25	35.50	361
7	1400	44.30	43.75	44.03	339
8	**1500**	**48.92**	**48.32**	**48.62**	**329**

Table 16 : Showing Load, measured deflections and calculated Eleq

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

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def(mm)	Eleq (t/sq m)
1	200	1.62	1.58	1.60	326
2	400	3.28	3.21	3.25	321
3	600	5.05	4.85	4.95	316
4	800	6.85	6.70	6.78	308
5	1000	8.75	8.55	8.65	301
6	1200	10.75	10.40	10.58	296
7	1400	12.85	12.45	12.65	288
8	1600	14.92	14.50	14.71	283
9	1800	16.70	16.61	16.66	281
10	2000	18.85	18.51	18.68	279
11	2200	20.92	20.36	20.64	278
12	2400	23.12	22.20	22.66	276
13	2600	25.30	23.90	24.60	275
14	2800	27.65	26.00	26.83	272
15	3000	29.95	27.85	28.90	270
16	3200	32.45	29.90	31.18	267
17	3400	35.85	33.02	34.44	257
18	3600	38.60	36.65	37.63	249
19	3800	41.88	39.05	40.47	245
20	4000	45.28	42.45	43.87	237
21	**4200**	**48.90**	**45.77**	**47.34**	**231**

Table 17 : Showing Load, measured deflections and calculated Eleq

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

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	2.21	2.16	2.19	412
2	400	4.62	4.45	4.54	397
3	600	7.19	6.90	7.05	383
4	800	9.75	9.45	9.60	375
5	1000	12.37	12.05	12.21	369
6	1200	15.40	15.02	15.21	355
7	1400	18.40	17.80	18.10	348
8	1600	21.55	20.95	21.25	339
9	1800	24.92	24.14	24.53	330
10	2000	28.60	27.65	28.13	320
11	2200	33.12	32.05	32.59	304
12	2400	37.90	36.82	37.36	289
13	2600	42.35	41.03	41.69	281
14	2800	**46.58**	**45.32**	**45.95**	**274**

05338

Table 18 : Showing Load, measured deflections and calculated Eleq

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

S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	3.05	3.02	3.04	[illegible]
2	400	6.45	6.35	6.40	447
3	600	9.95	9.75	9.85	[illegible]
4	[illegible]	13.52	13.28	13.40	[illegible]
5	1000	17.35	17.05	17.20	[illegible]
6	1200	21.45	21.05	21.25	404
7	1400	26.35	25.85	26.10	383
8	1600	31.44	30.75	31.10	368
9	1800	37.35	36.50	36.93	348
10	2000	42.95	41.85	42.40	337
11	2200	**48.25**	**46.60**	**47.43**	331

Table 19 : Showing Load, measured deflections and calculated Eleq

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

S.No.	Load (Kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	3.58	3.52	3.55	601
2	400	7.35	7.24	7.30	585
3	600	11.41	11.11	11.26	568
4	800	16.01	15.21	15.61	547
5	[illegible]	23.48	22.50	22.99	[illegible]
6	[illegible]	30.80	29.90	30.35	[illegible]
7	1400	40.15	39.20	39.68	376
8	1600	**50.12**	**48.15**	**49.14**	347

Table20 : Showing Load, measured deflections and calculated Eleq

05339

Sleeper 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	1.76	1.68	1.72	303
2	400	3.90	3.75	3.83	272
3	600	6.02	5.85	5.94	263
4	800	8.34	8.05	8.20	254
5	1000	10.80	10.45	10.63	245
6	1200	13.15	12.70	12.93	242
7	1400	15.84	15.04	15.44	236
8	1600	18.46	17.36	17.91	233
9	1800	21.21	19.95	20.58	228
10	2000	24.30	22.85	23.58	221
11	2200	27.08	25.50	26.29	218
12	2400	29.99	28.20	29.10	215
13	2600	32.20	30.10	31.15	217
14	2800	35.12	32.95	34.04	214
15	3000	37.90	35.67	36.79	212
16	3200	41.35	38.75	40.05	208
17	3400	44.25	41.30	42.78	207
18	3600	47.15	44.05	45.60	206
19	**3800**	**50.10**	**47.00**	**48.55**	**204**

Table 21 : Showing Load, measured deflections and calculated Eleq

Sleeper 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	2.49	2.40	2.45	368
2	400	5.55	5.40	5.48	329
3	600	8.85	8.65	8.75	309
4	800	12.58	12.25	12.42	290
5	1000	16.35	15.65	16.00	281
6	1200	20.15	19.30	19.73	274
7	1400	24.20	23.15	23.68	266
8	1600	28.40	27.00	27.70	260
9	1800	32.85	31.10	31.98	253
10	2000	37.25	35.15	36.20	249
11	2200	41.89	39.05	40.47	245
12	**2400**	**47.05**	**44.05**	**45.55**	**237**

Table 22 : Showing Load, measured deflections and calculated Eleq

05340

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

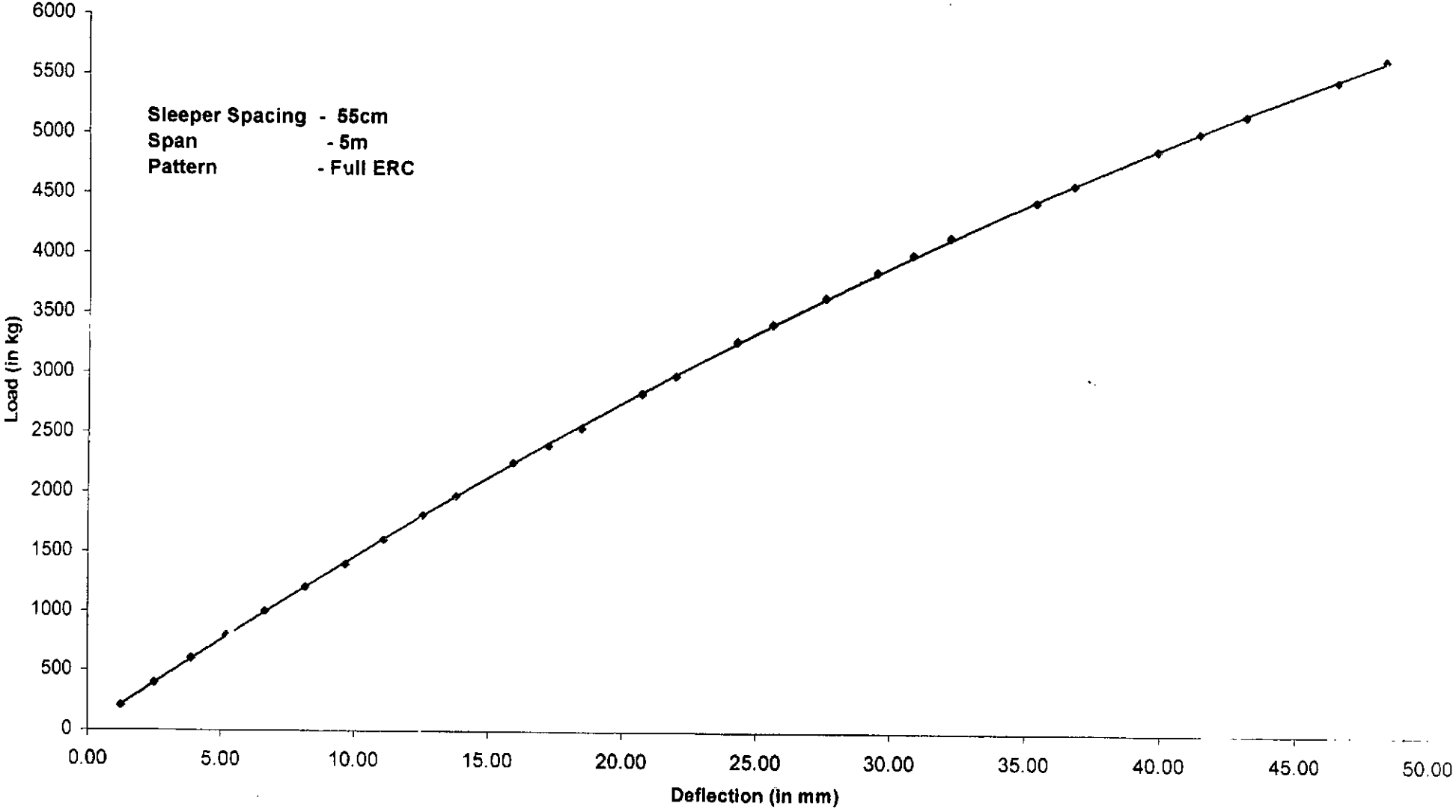
S.No.	Load (kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	3.28	3.20	3.24	441
2	400	7.90	7.70	7.80	366
3	600	13.16	12.35	12.76	336
4	800	18.11	17.15	17.63	324
5	1000	24.22	22.85	23.54	304
6	1200	30.26	28.25	29.26	293
7	1400	37.48	35.04	36.26	276
8	1600	44.50	41.95	43.23	265
9	1800	**50.34**	**47.75**	**49.05**	262

Table 23 : Showing Load, measured deflections and calculated Eleq

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

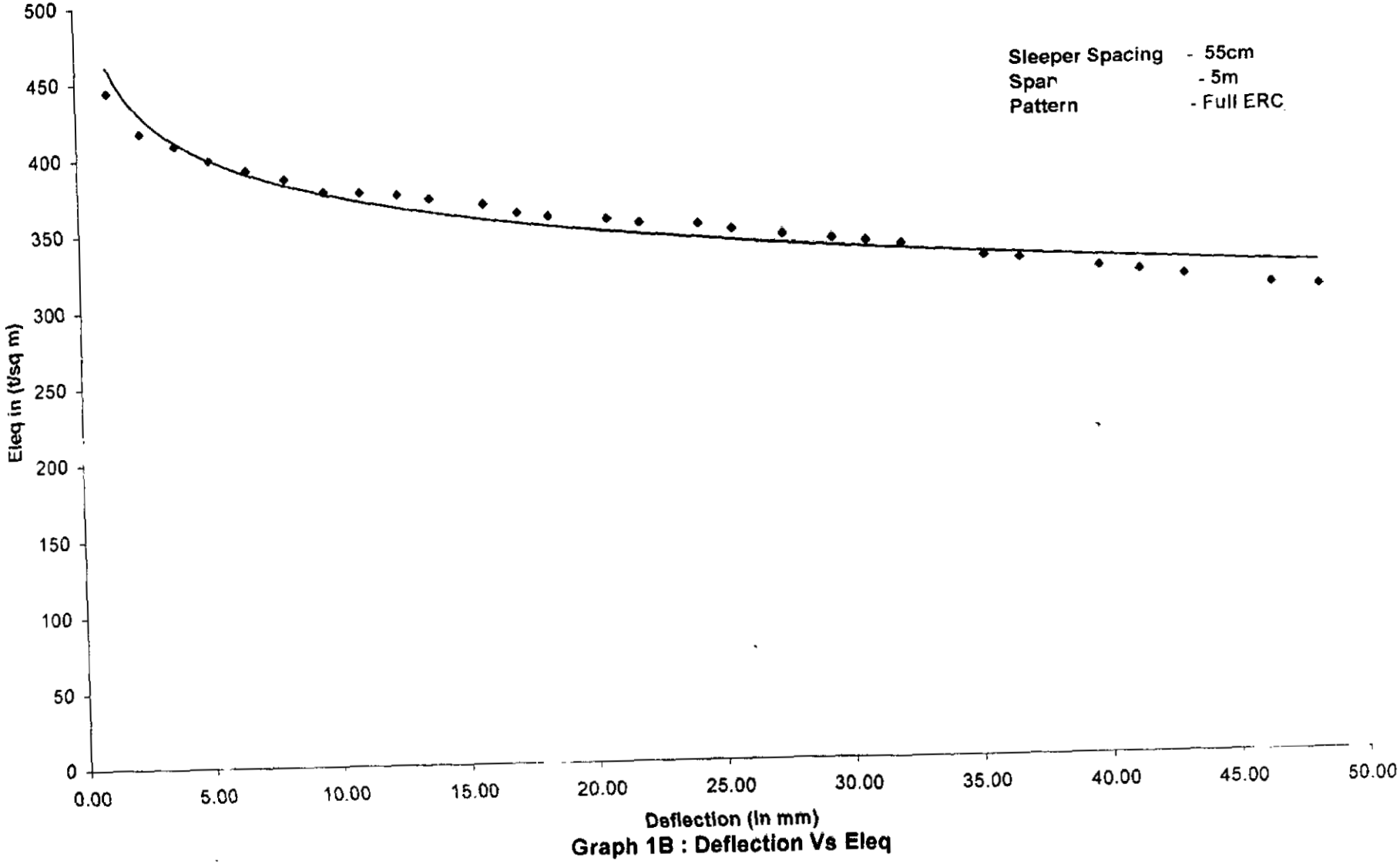
S.No.	Load (Kg)	Def 1 (mm)	Def 2 (mm)	Avg Def (mm)	Eleq (t/sq m)
1	200	4.40	4.30	4.35	490
2	400	9.65	9.35	9.50	449
3	600	15.82	15.22	15.52	412
4	800	26.22	25.14	25.68	332
5	1000	37.20	35.05	36.13	295
6	1200	**48.60**	**44.50**	**46.55**	275

Table 24 : Showing Load, measured deflections and calculated Eleq

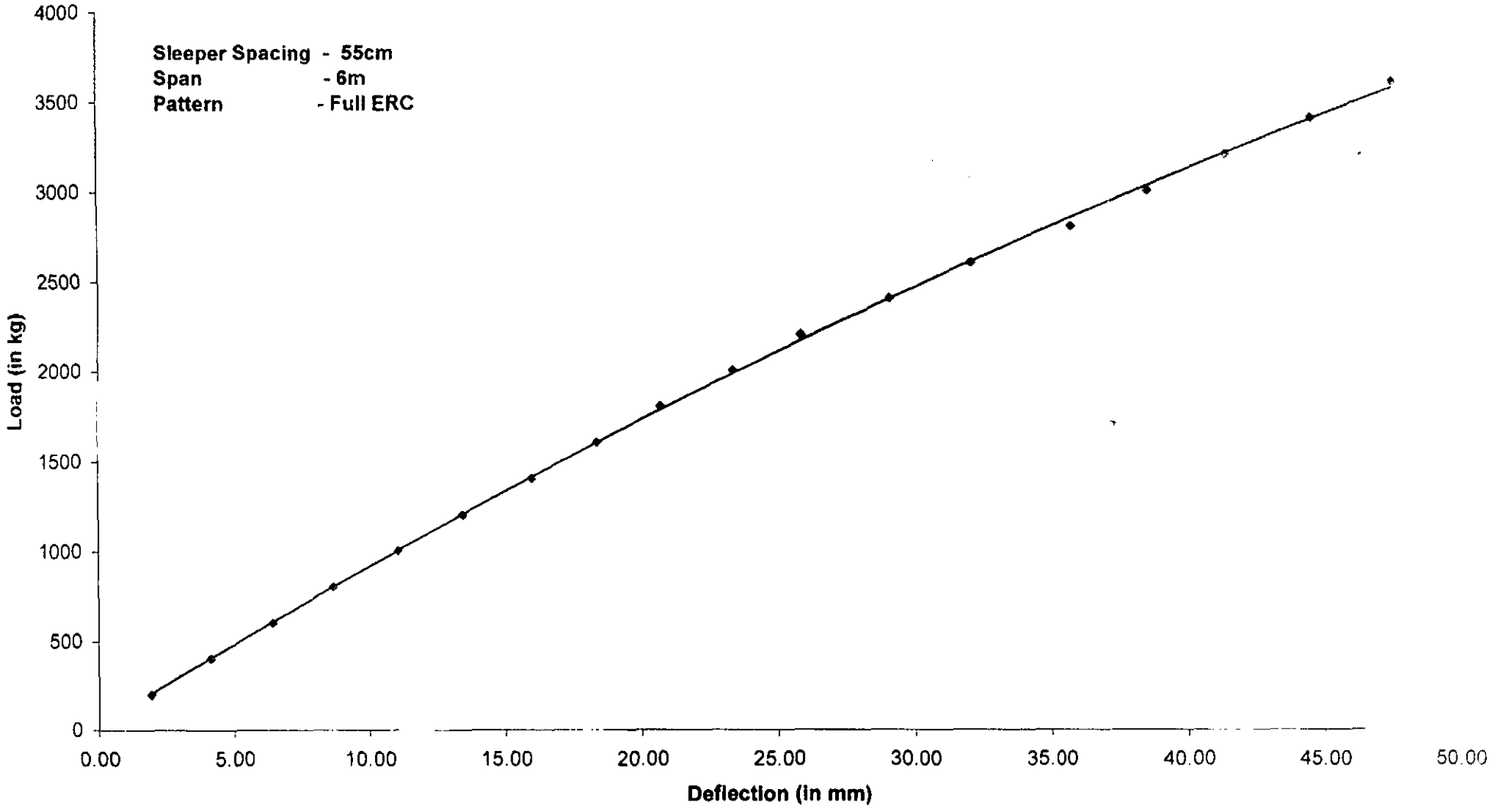


Graph 1A : Load Vs Deflection

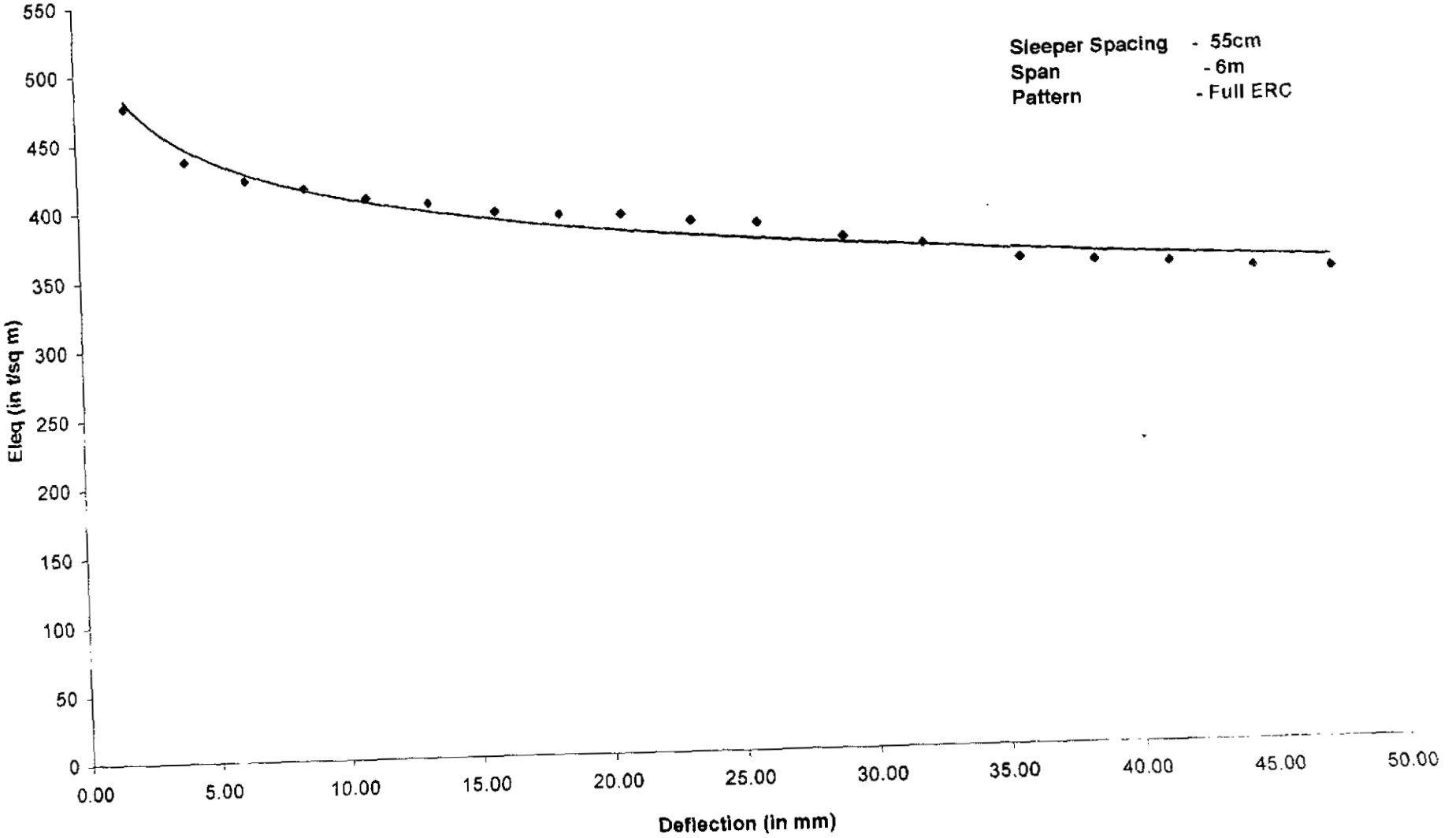
05342



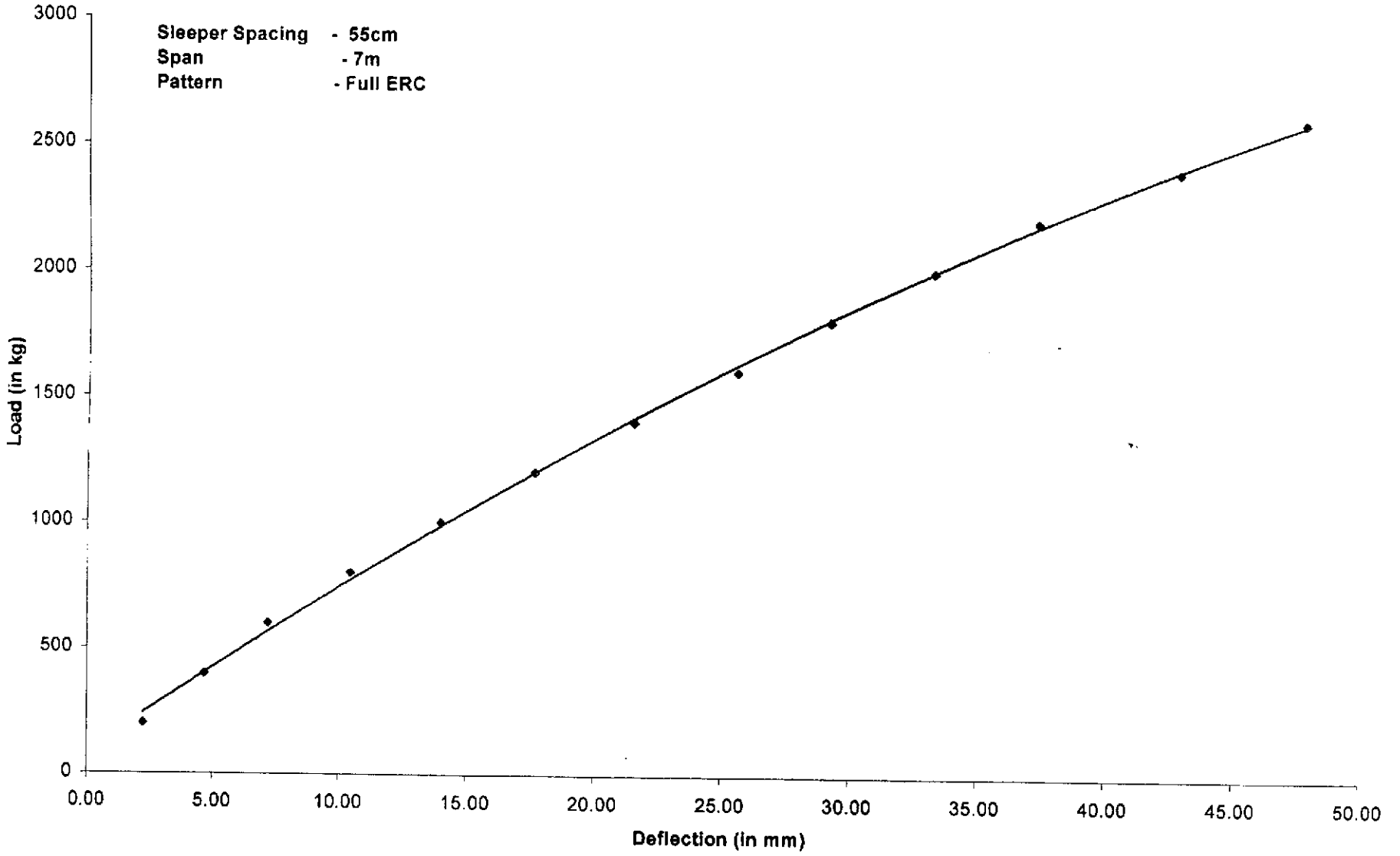
Graph 1B : Deflection Vs Eleq



Graph 2A : Load Vs Deflection

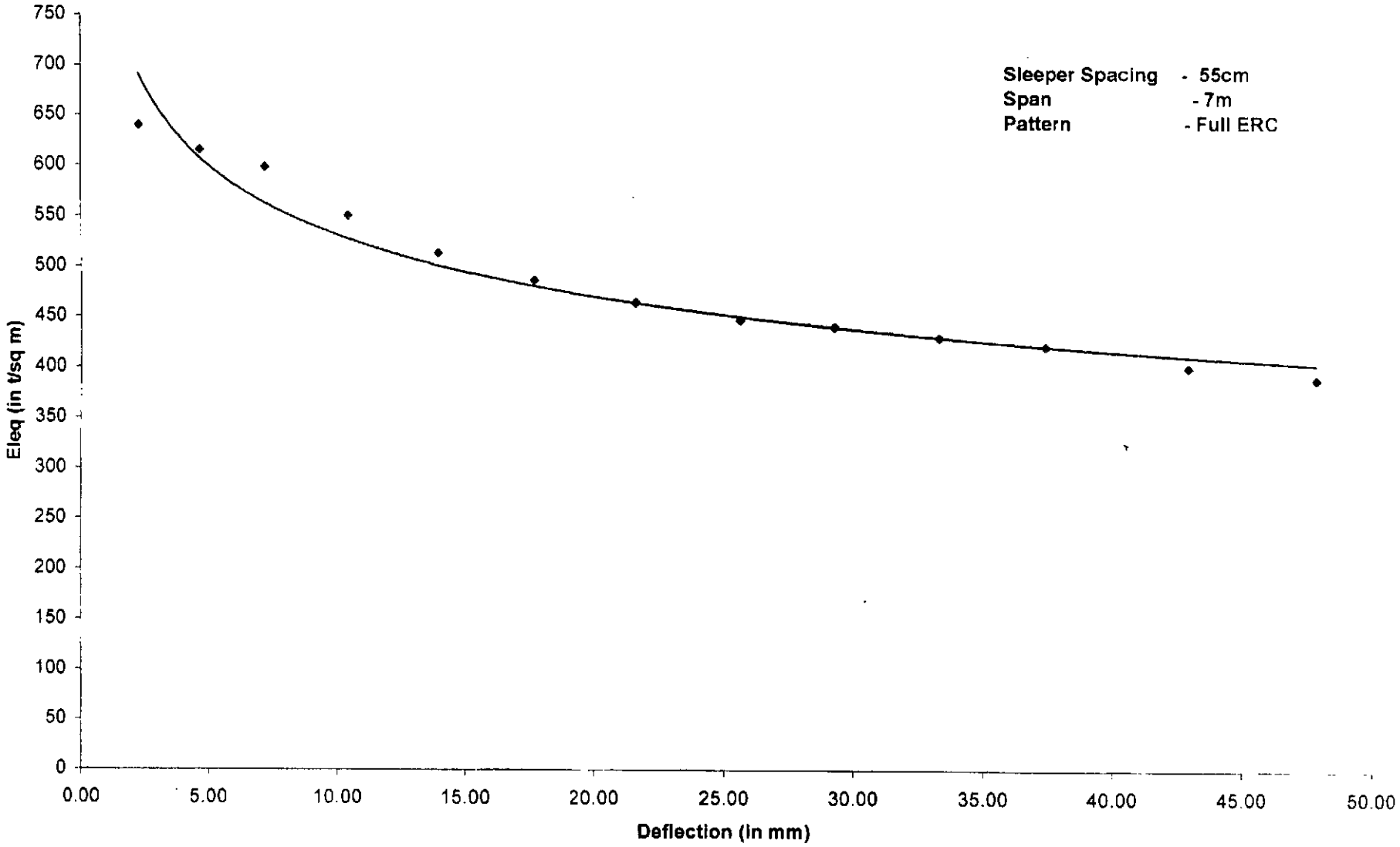


Graph 2B :Deflection Vs Eleq

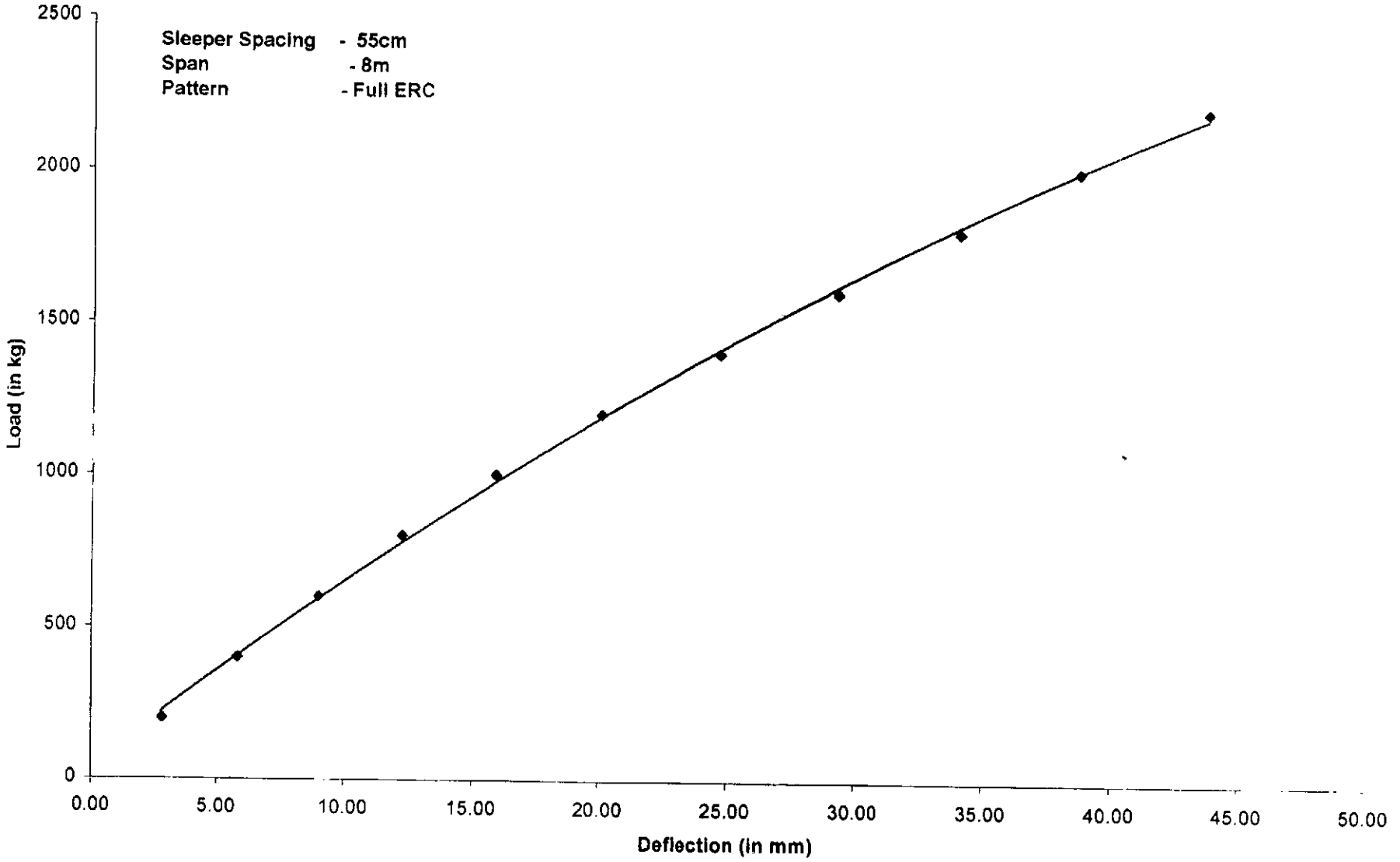


Graph 3A : Load Vs Deflection

05346

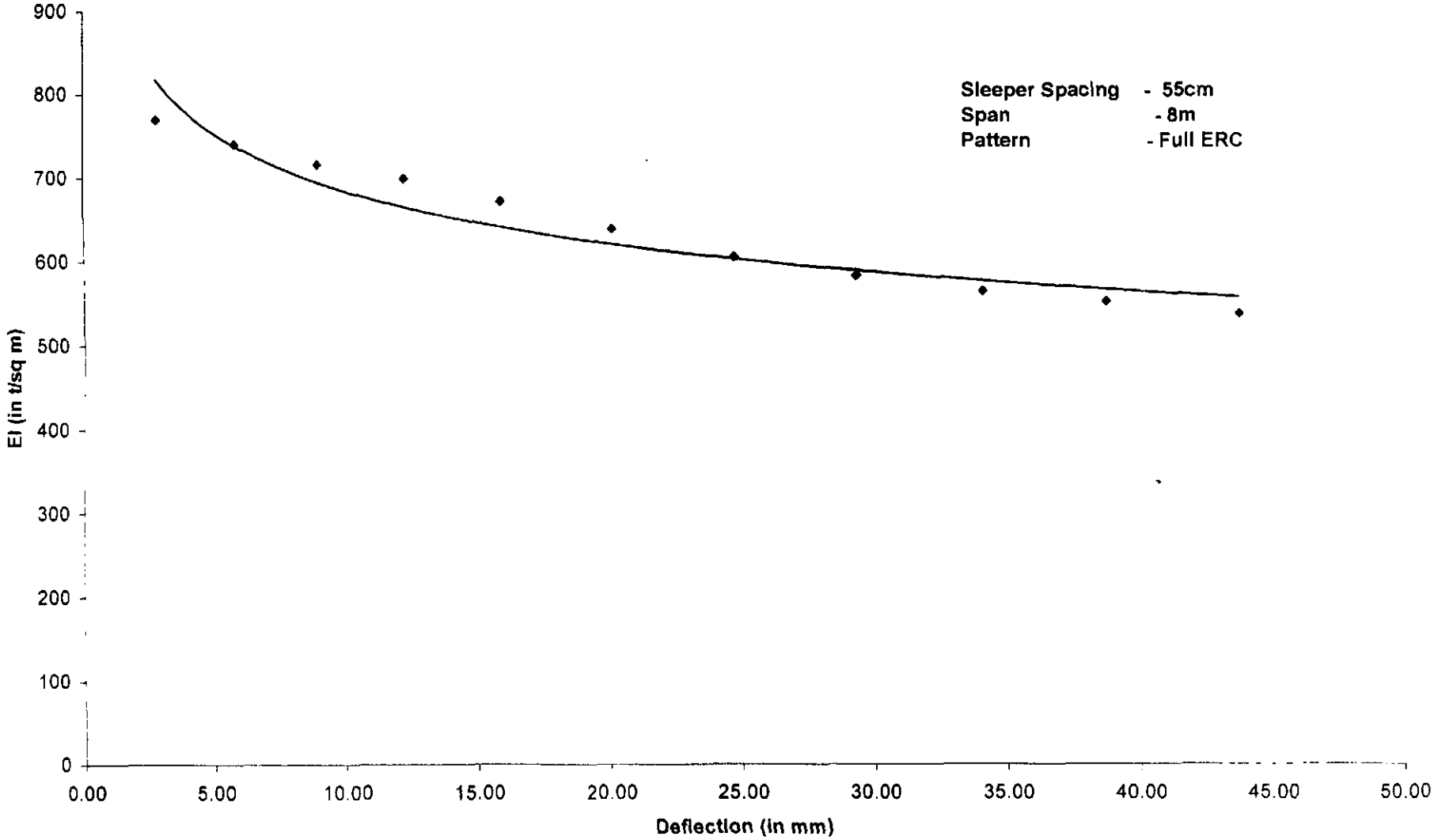


Graph 3B : Deflection Vs Eleq

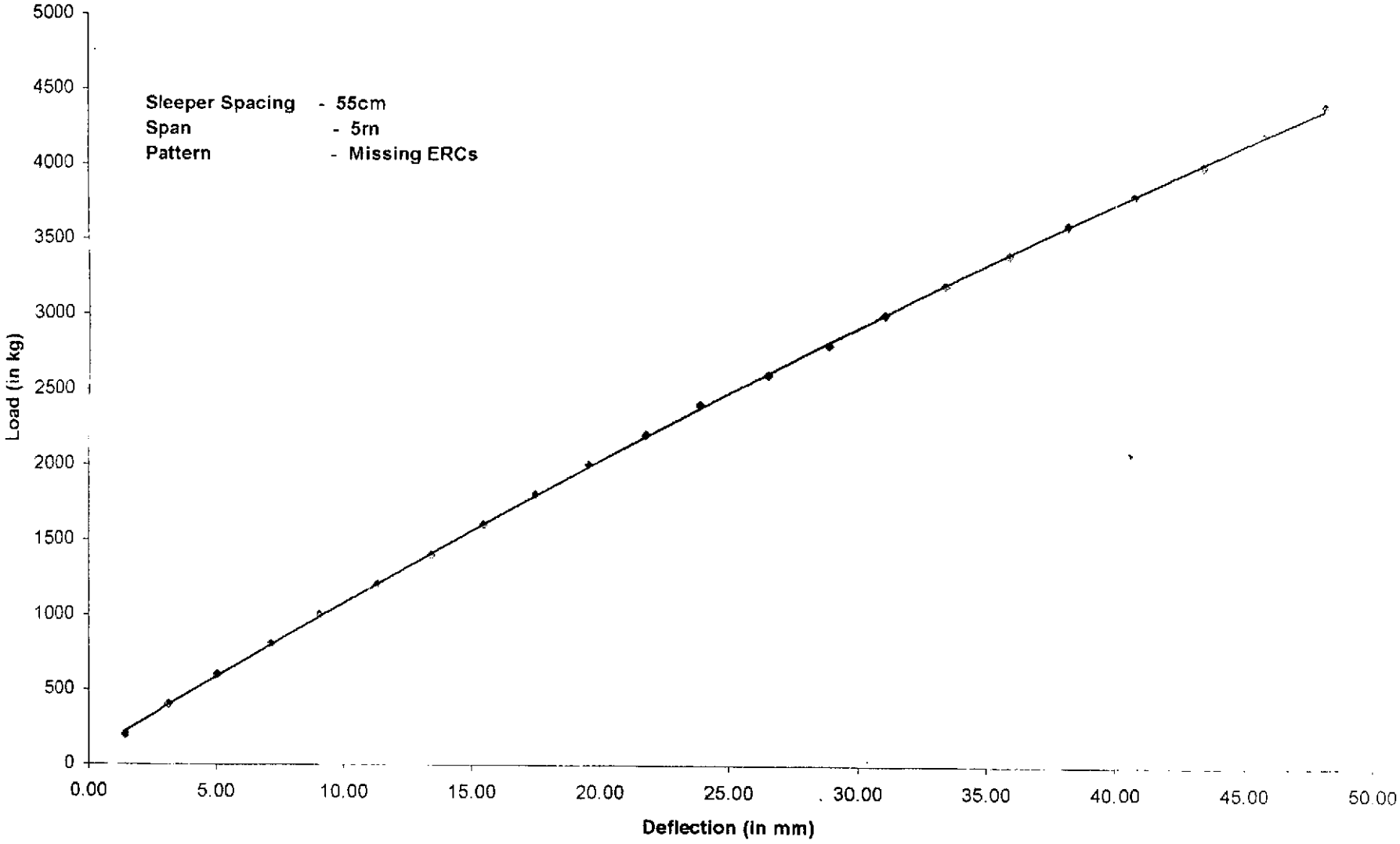


Graph 4A : Load Vs Deflection

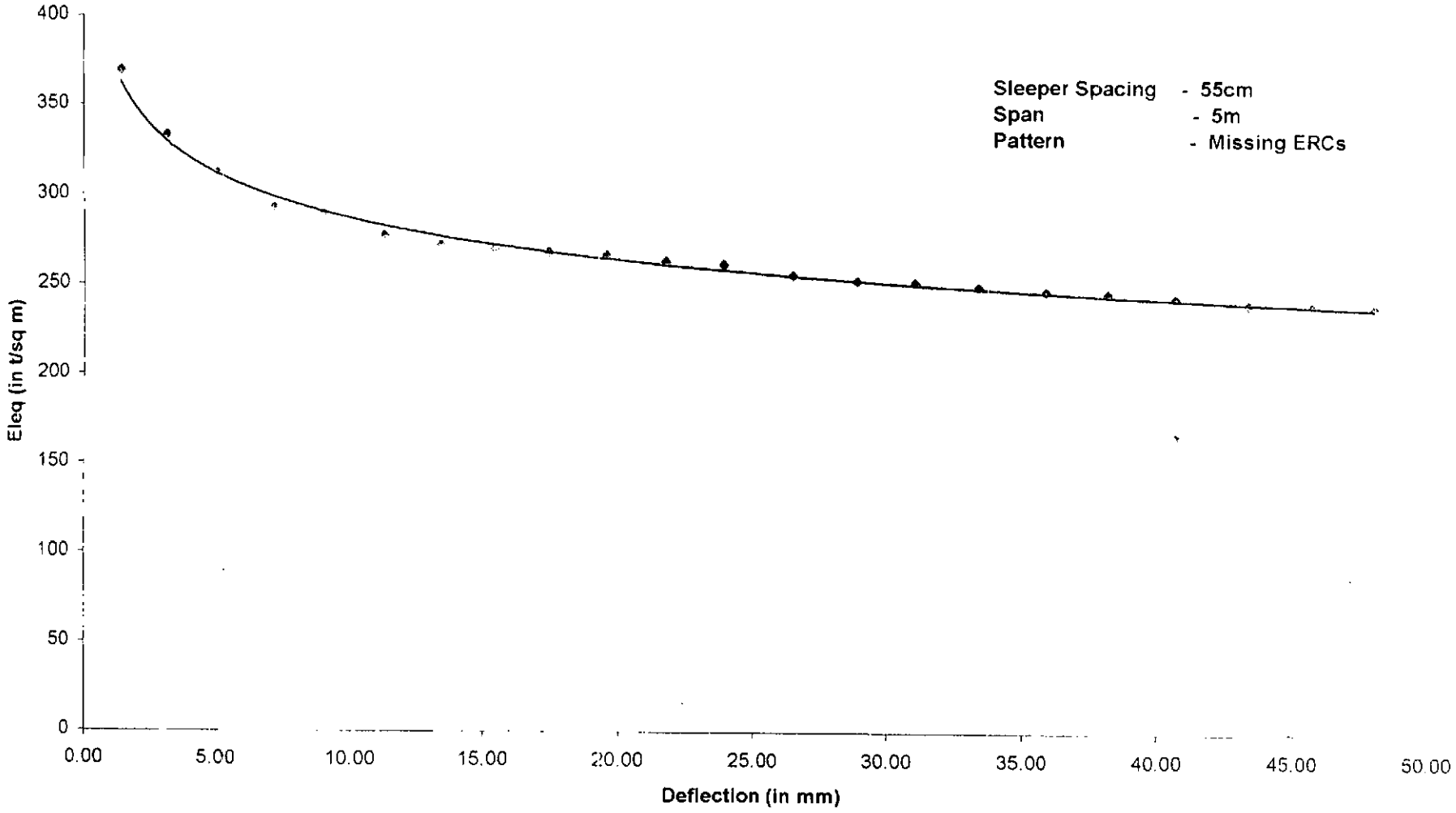
05348



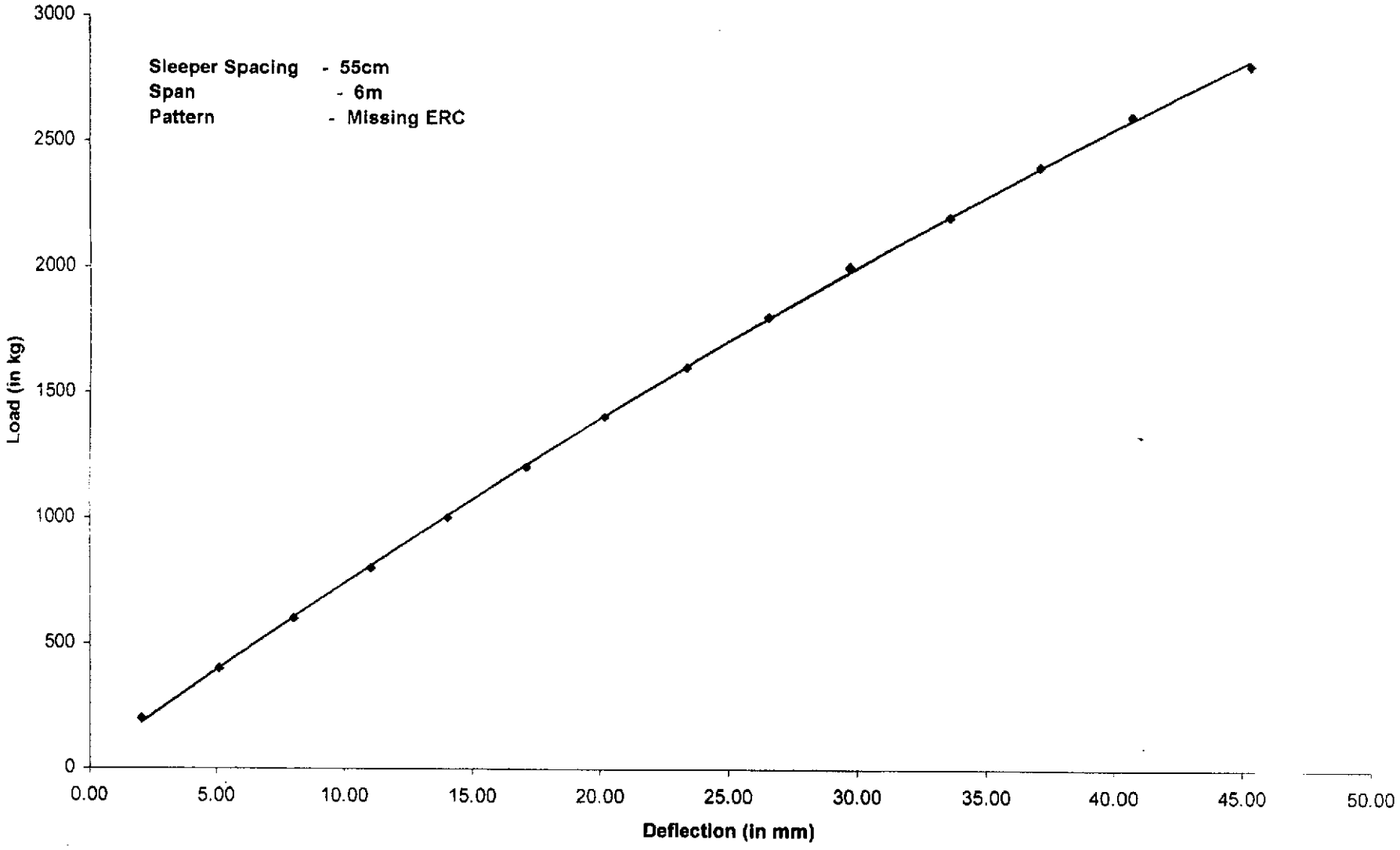
Graph 4B : Deflection Vs Eleq



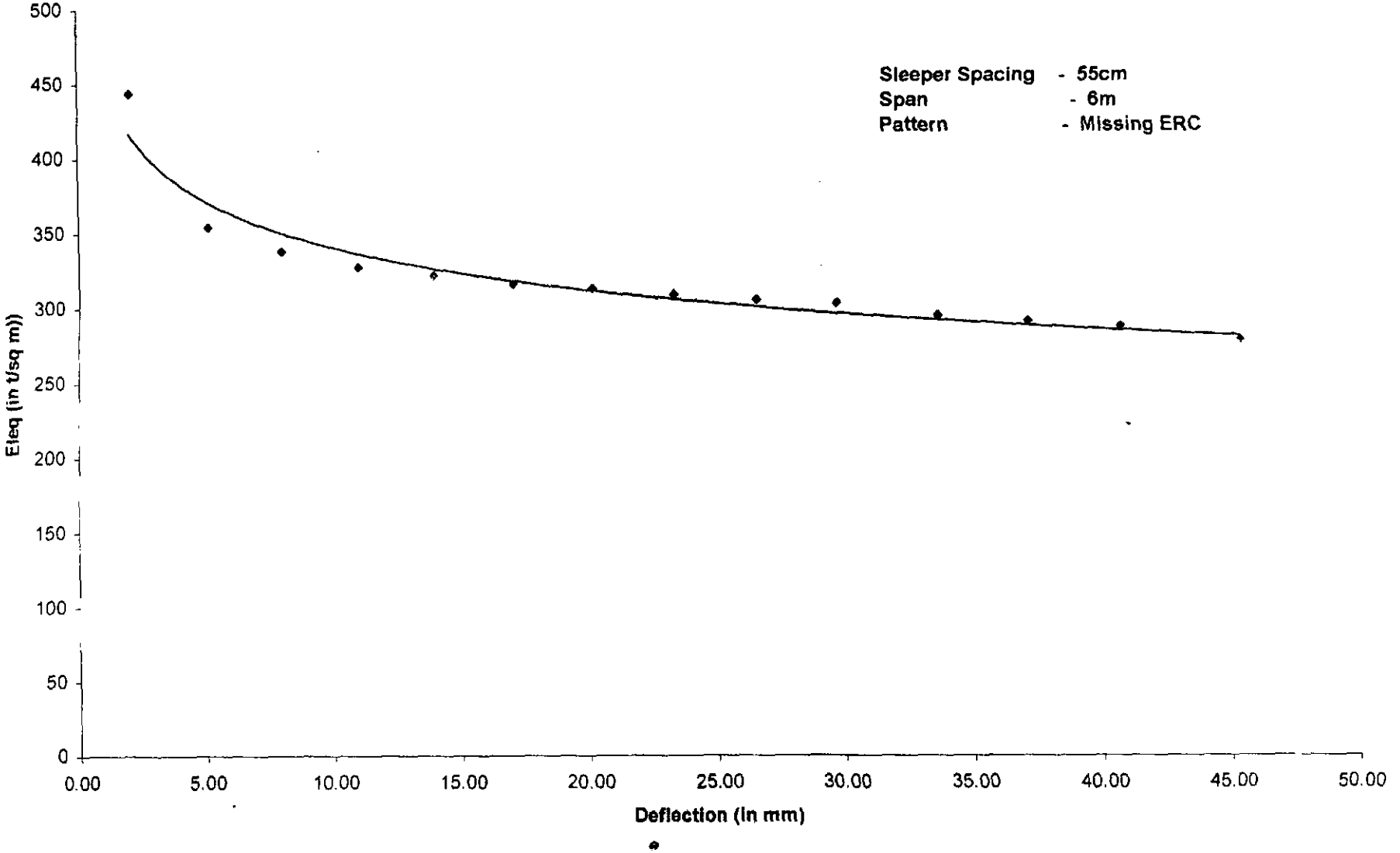
Graph 5A : Load Vs Deflection



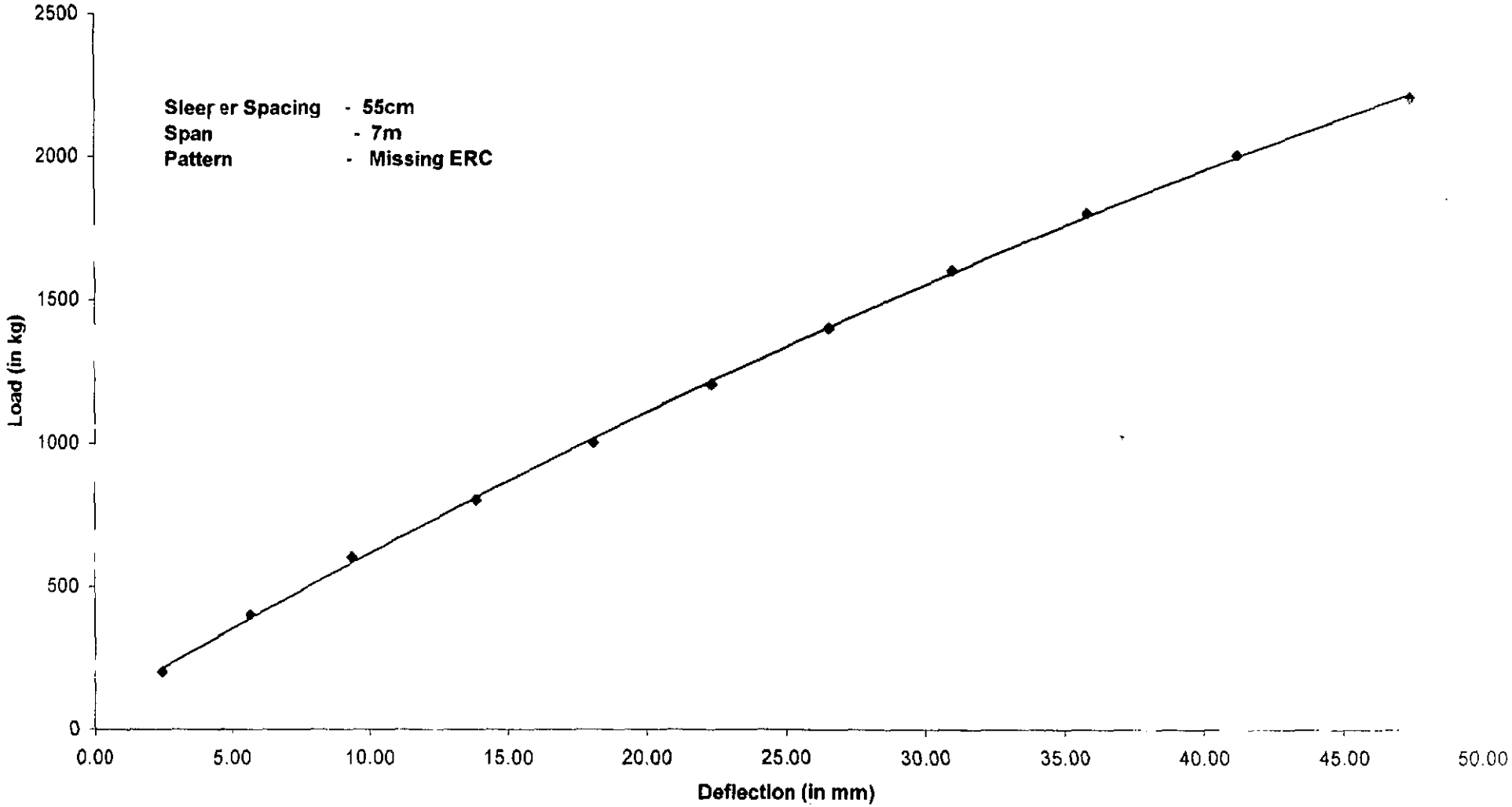
Graph 5B : Deflection Vs Eleq



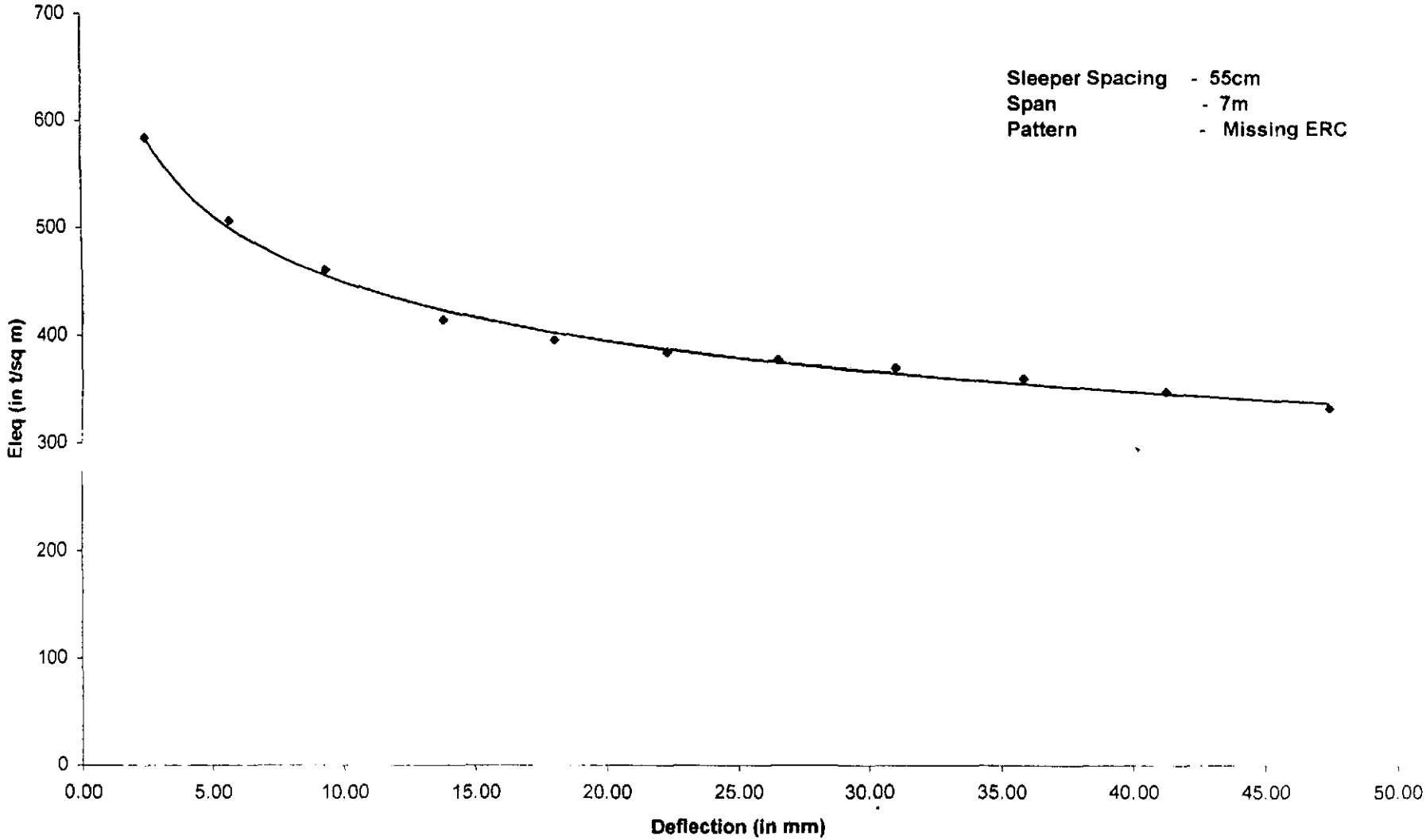
Graph 6A : Load Vs Deflection



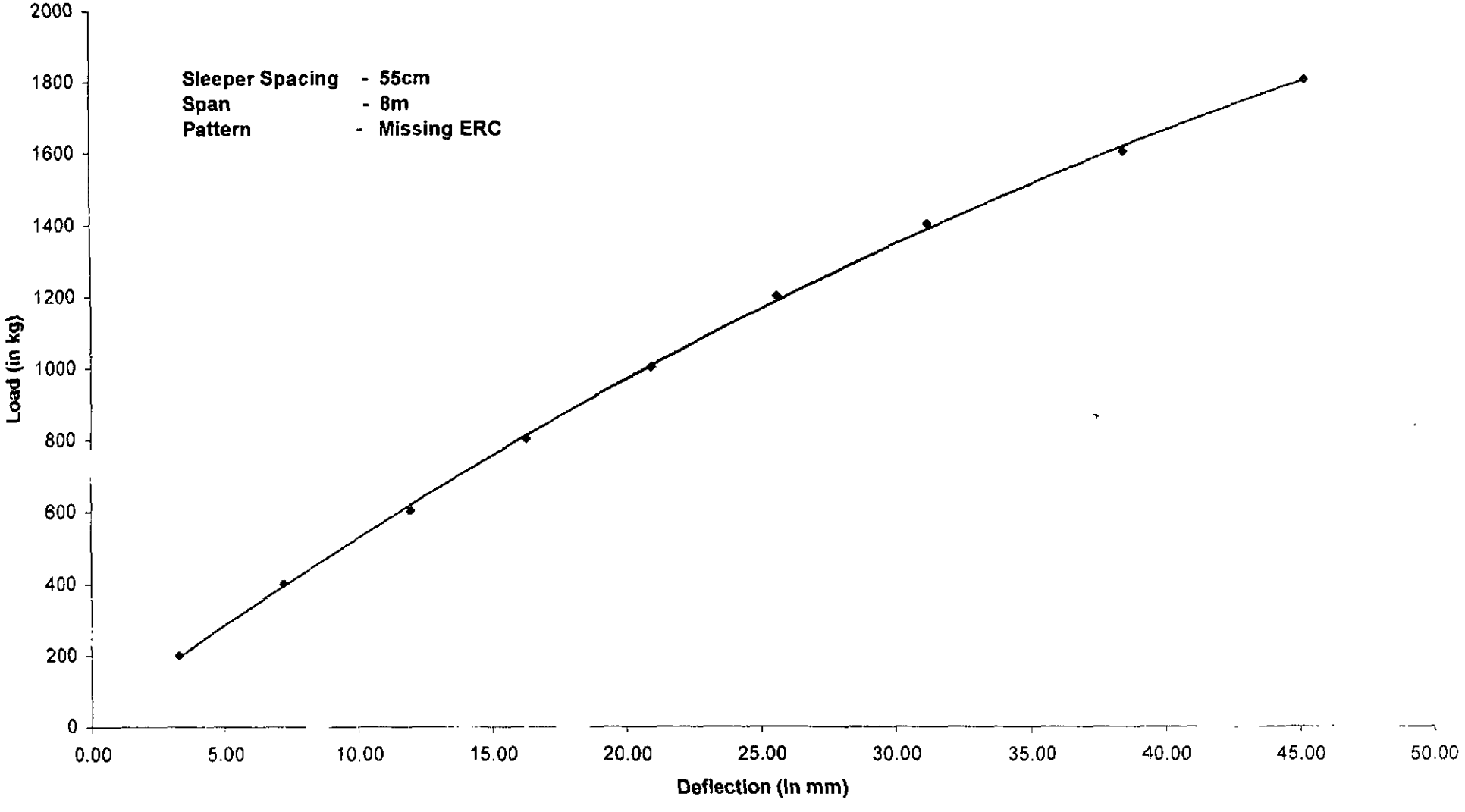
Graph 6B : Deflection Vs Eleq



Graph 7A : Load Vs Deflection

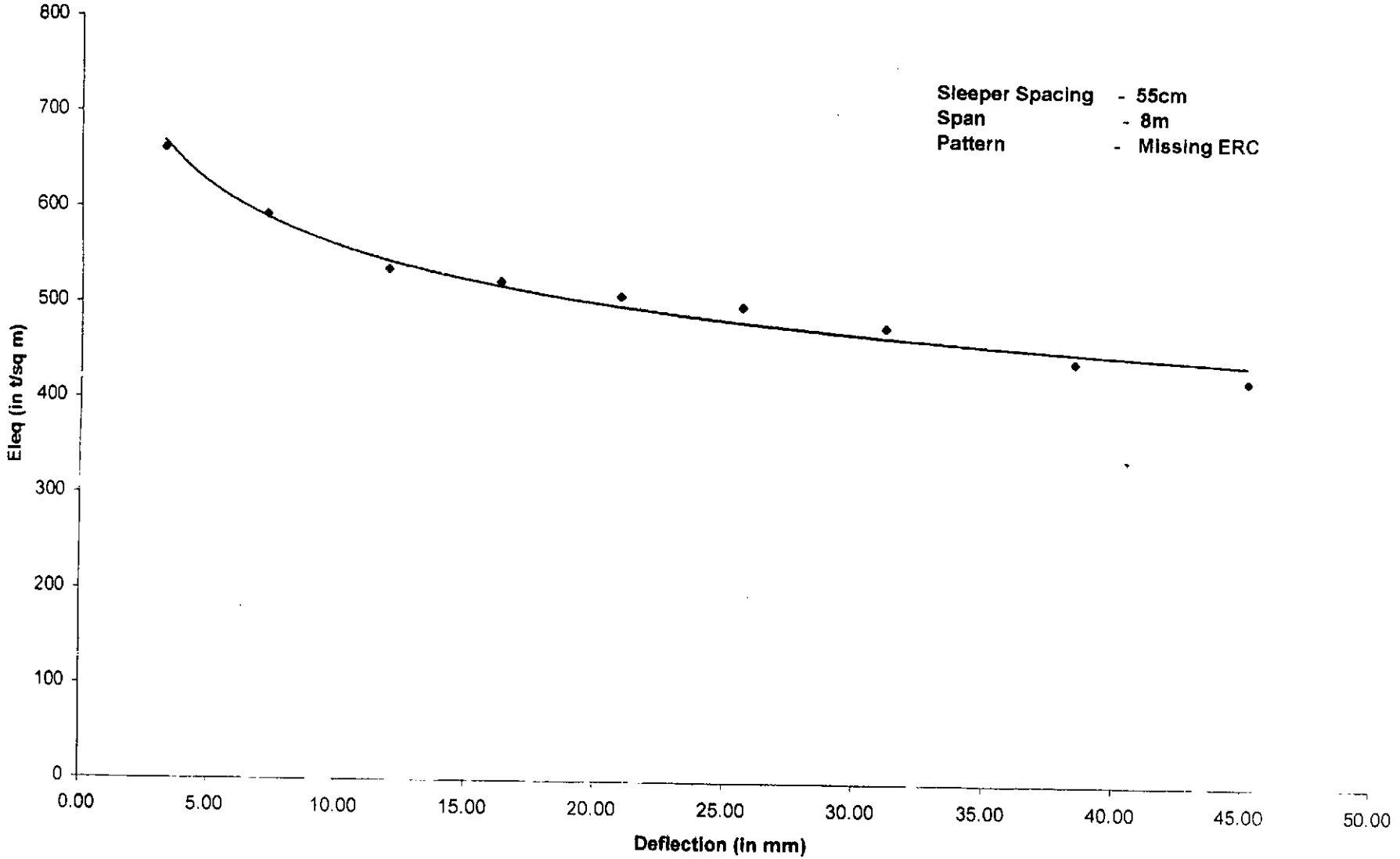


Graph7B : Deflection Vs Eleq



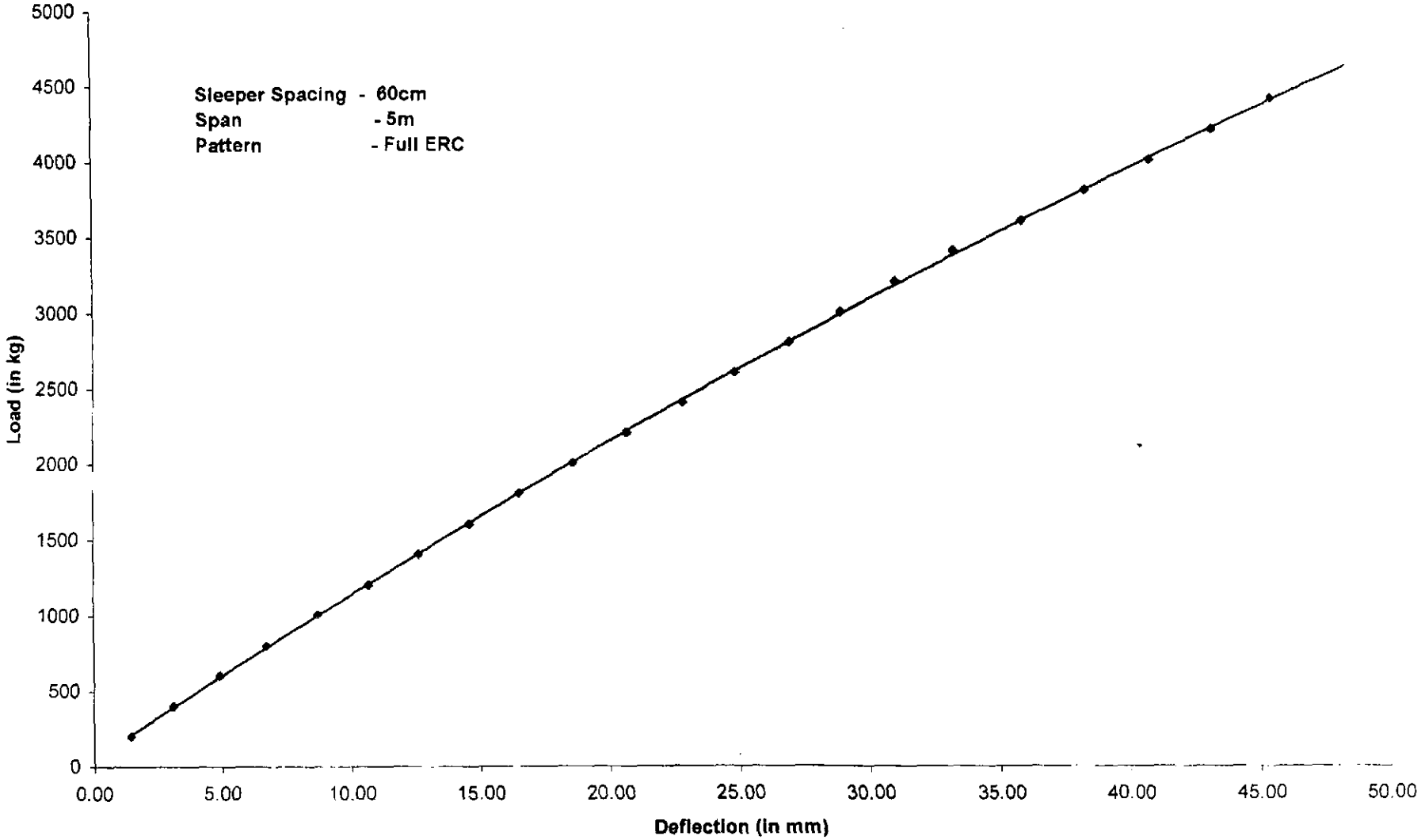
Graph 8A : Load Vs Deflection

05355



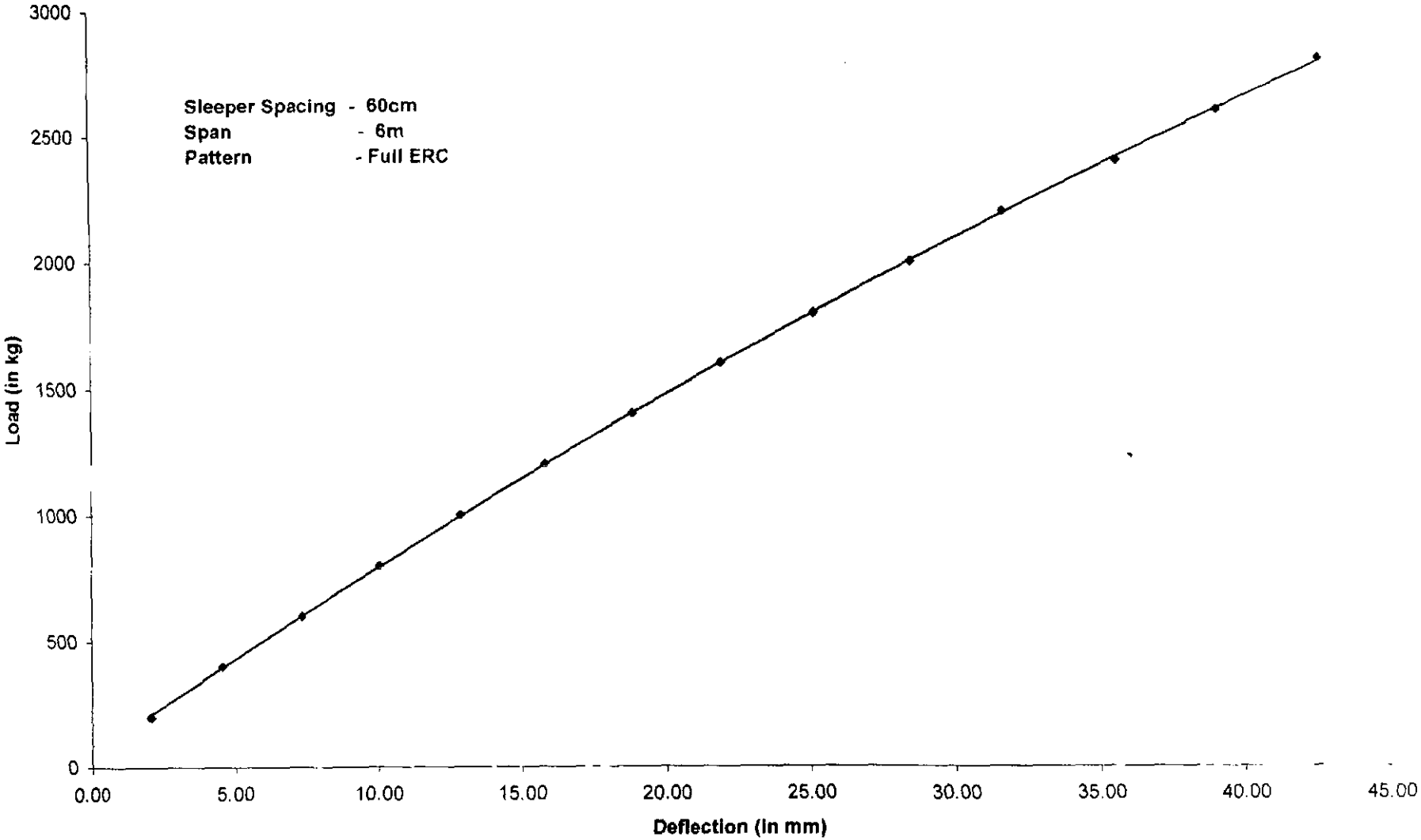
Graph 8B : Deflection Vs Eleq

05356

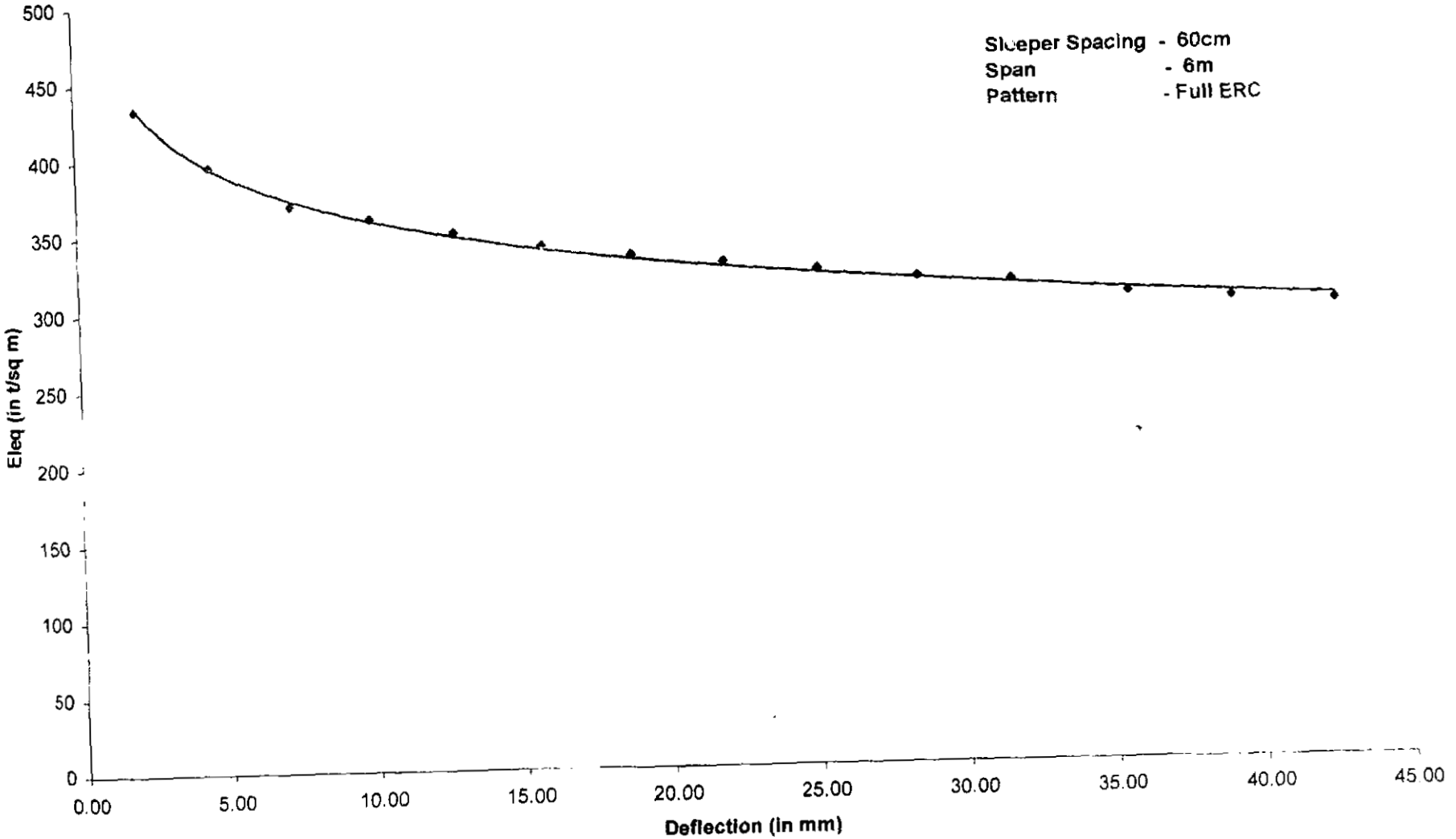


Graph 9A : Load Vs Deflection

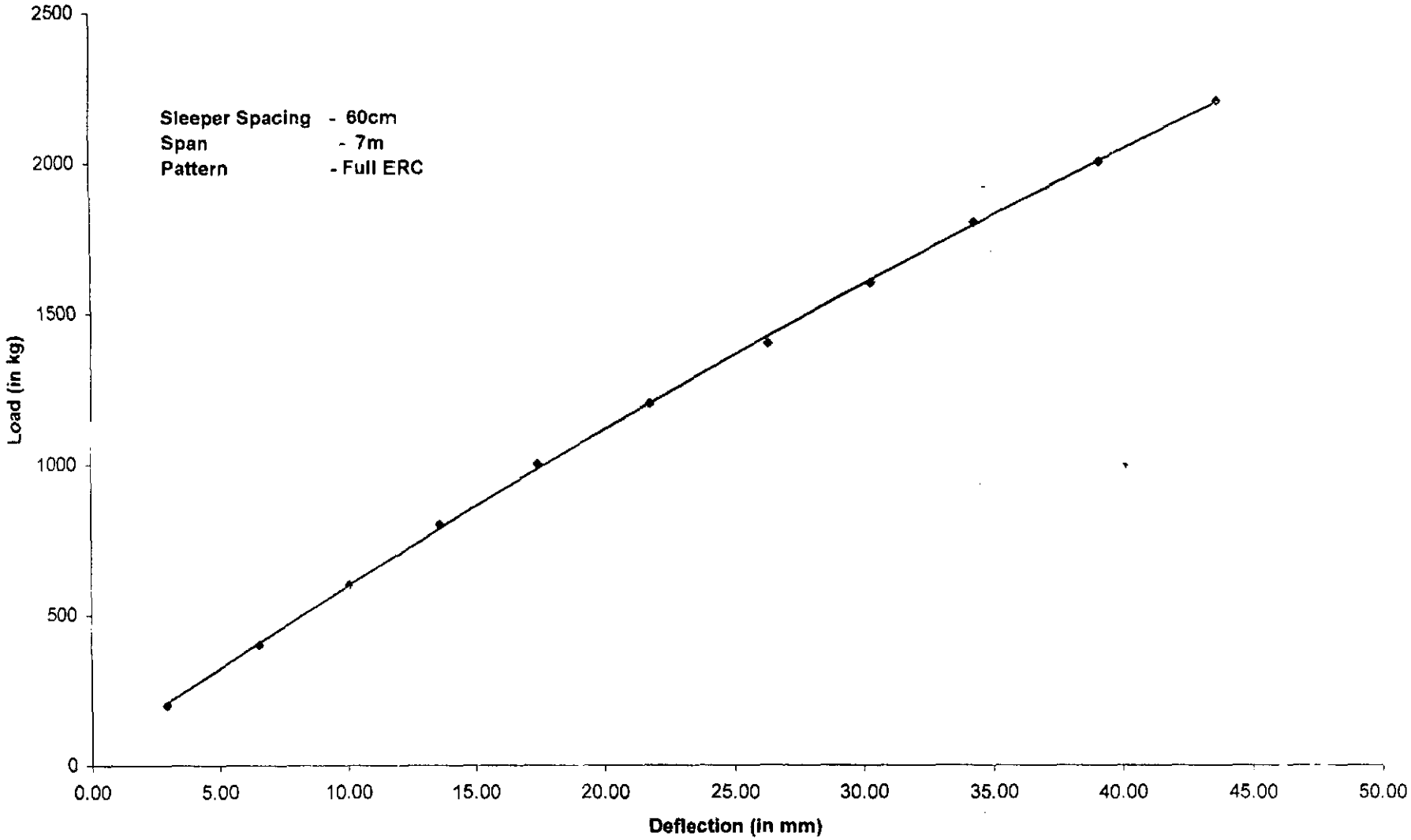
05357



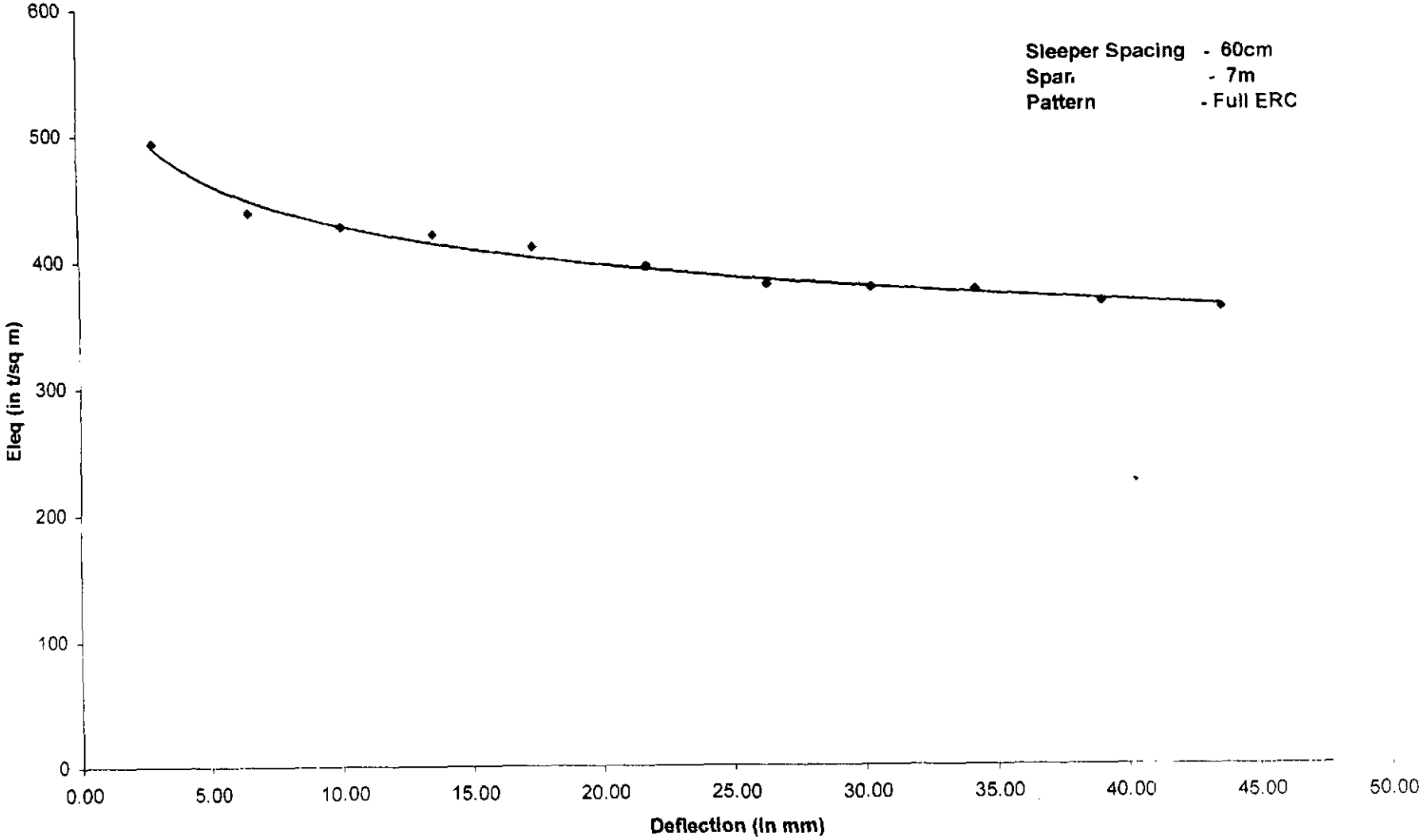
Graph 10A : Load Vs Deflection



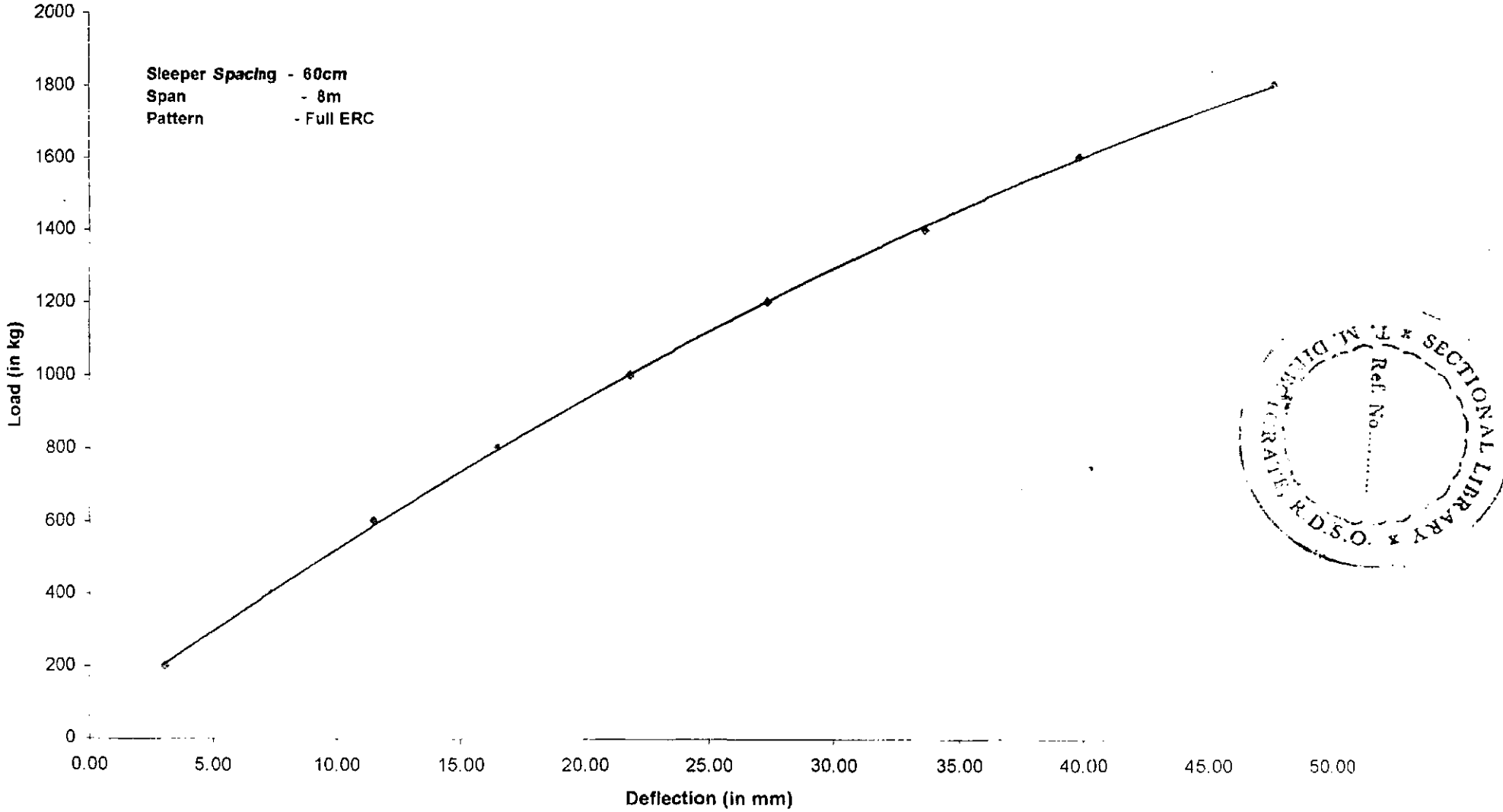
Graph 10B : Deflection Vs Eleq



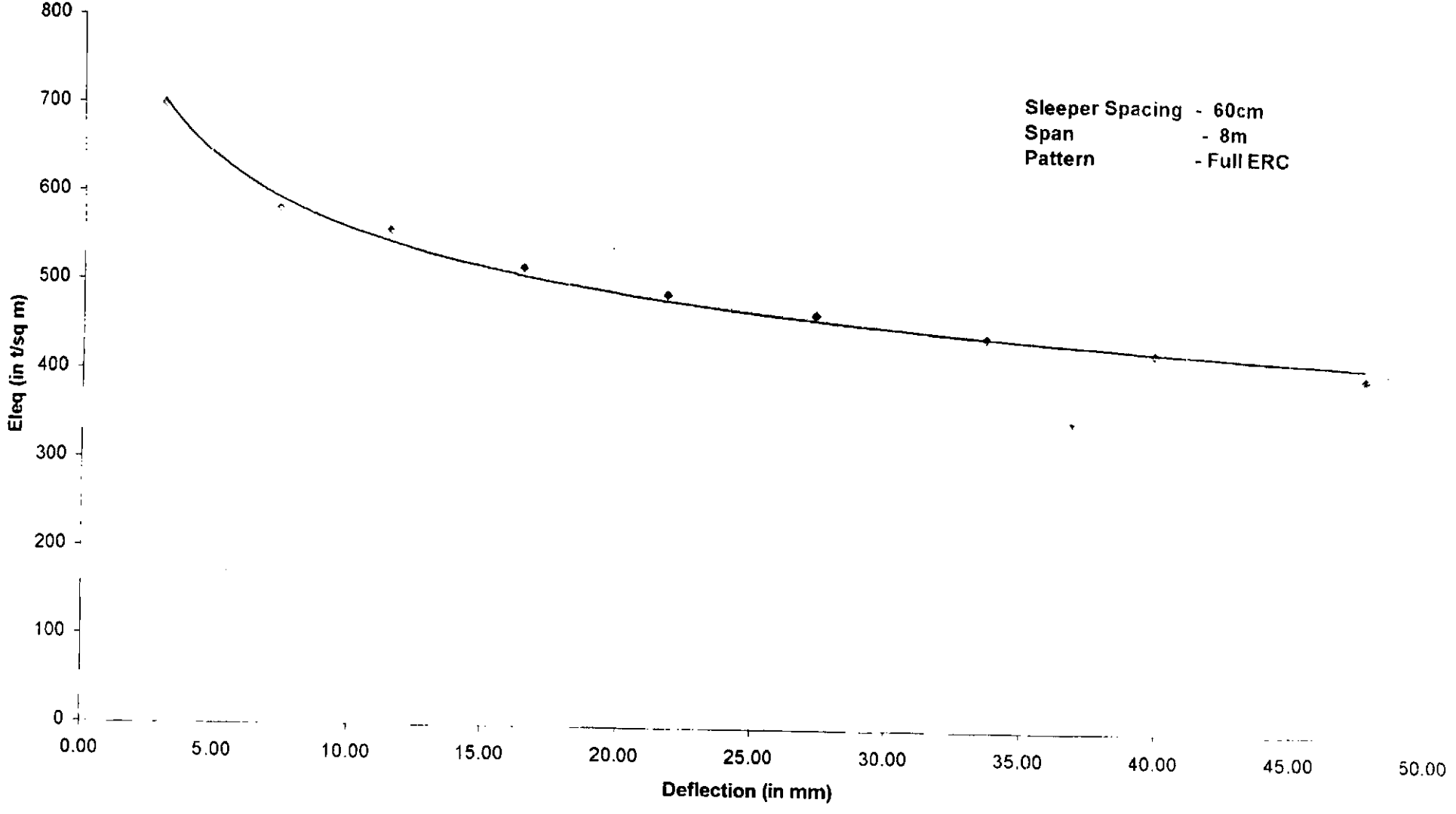
Graph 11A : Load Vs Deflection



Graph 11B : Deflection Vs Eleq

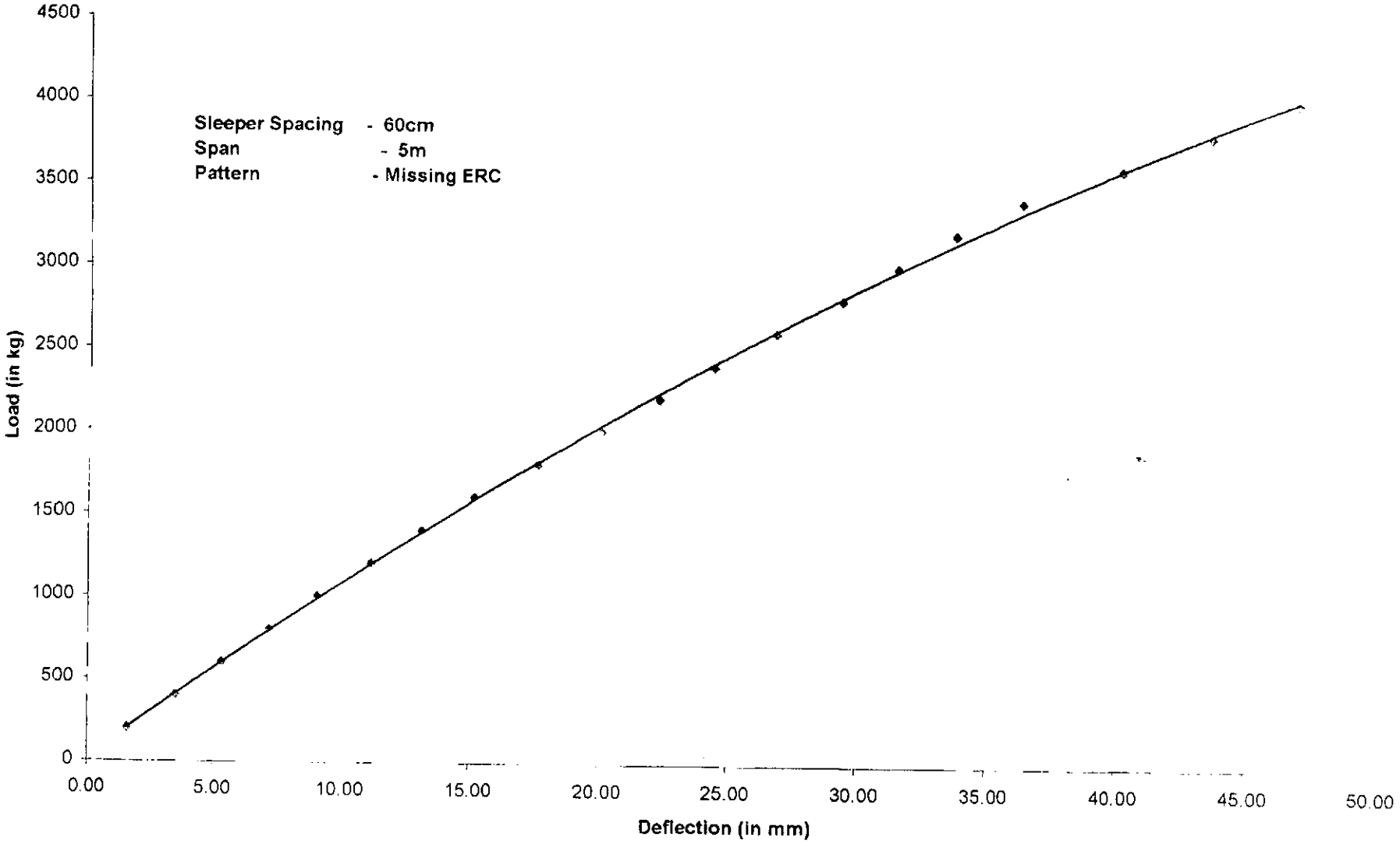


Graph 12A : Load Vs Deflection

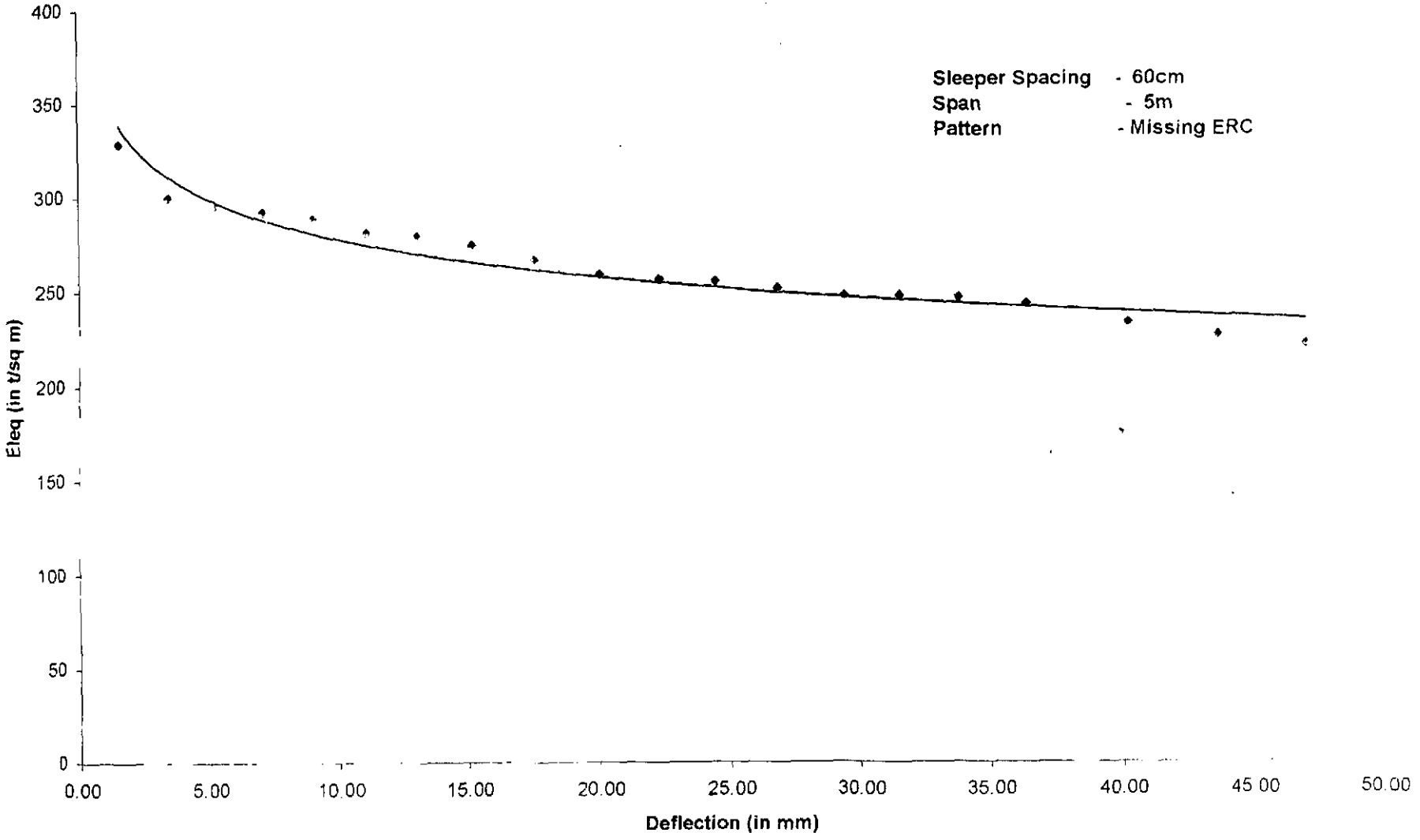


Graph 12B :Deflection Vs Eleq

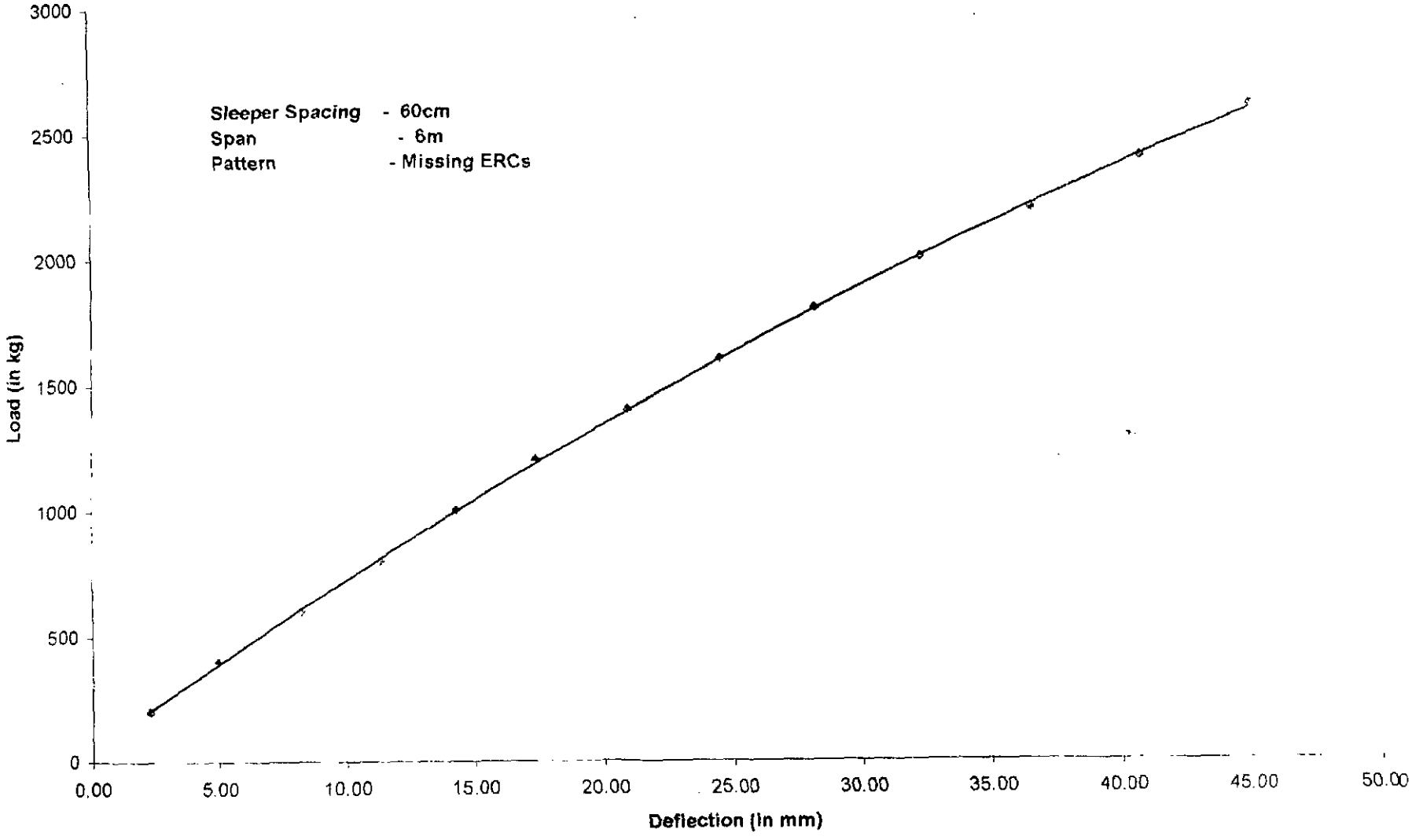
05364



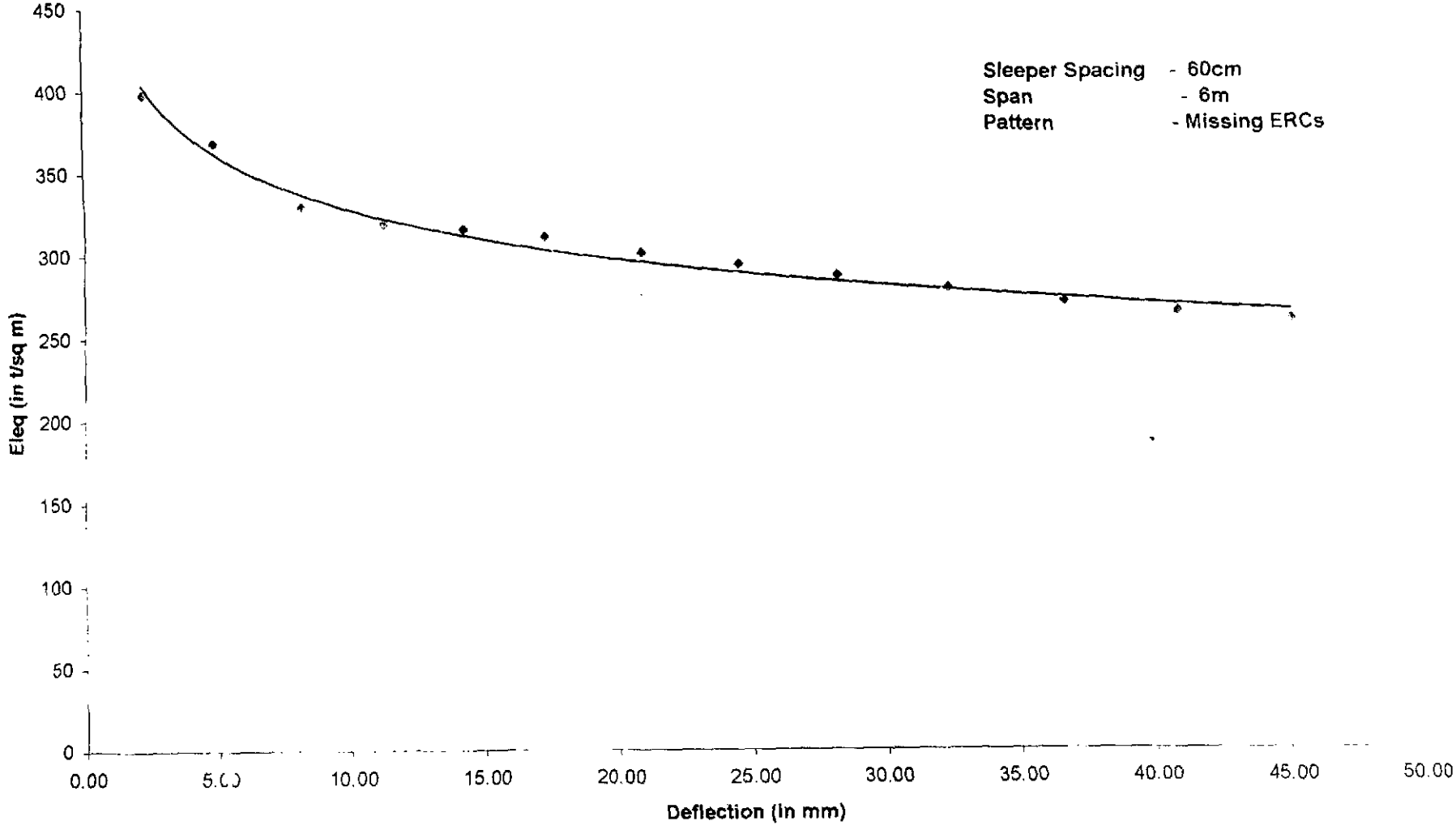
Graph 13A : Load Vs Deflection



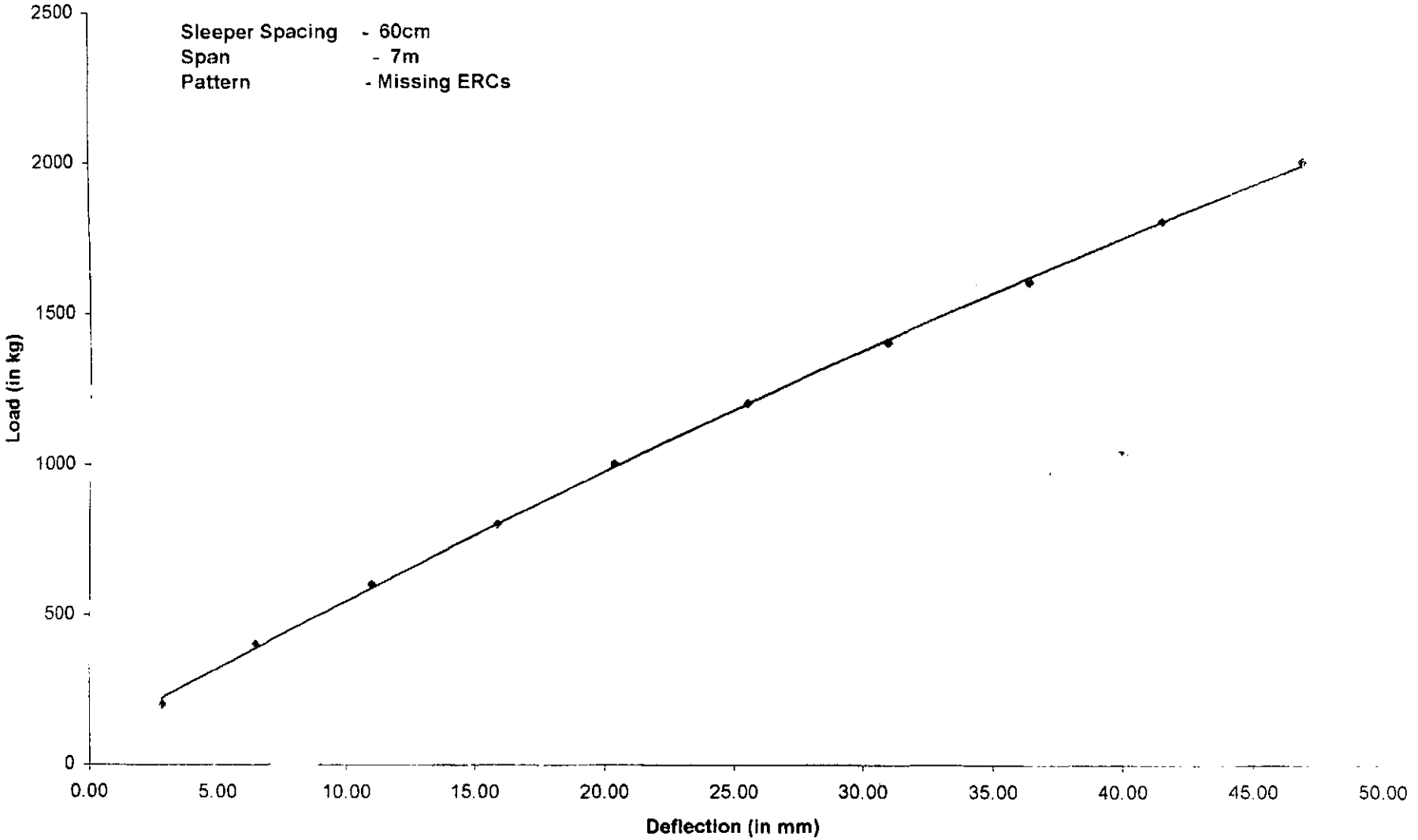
Graph 13B : Deflection Vs Eleq



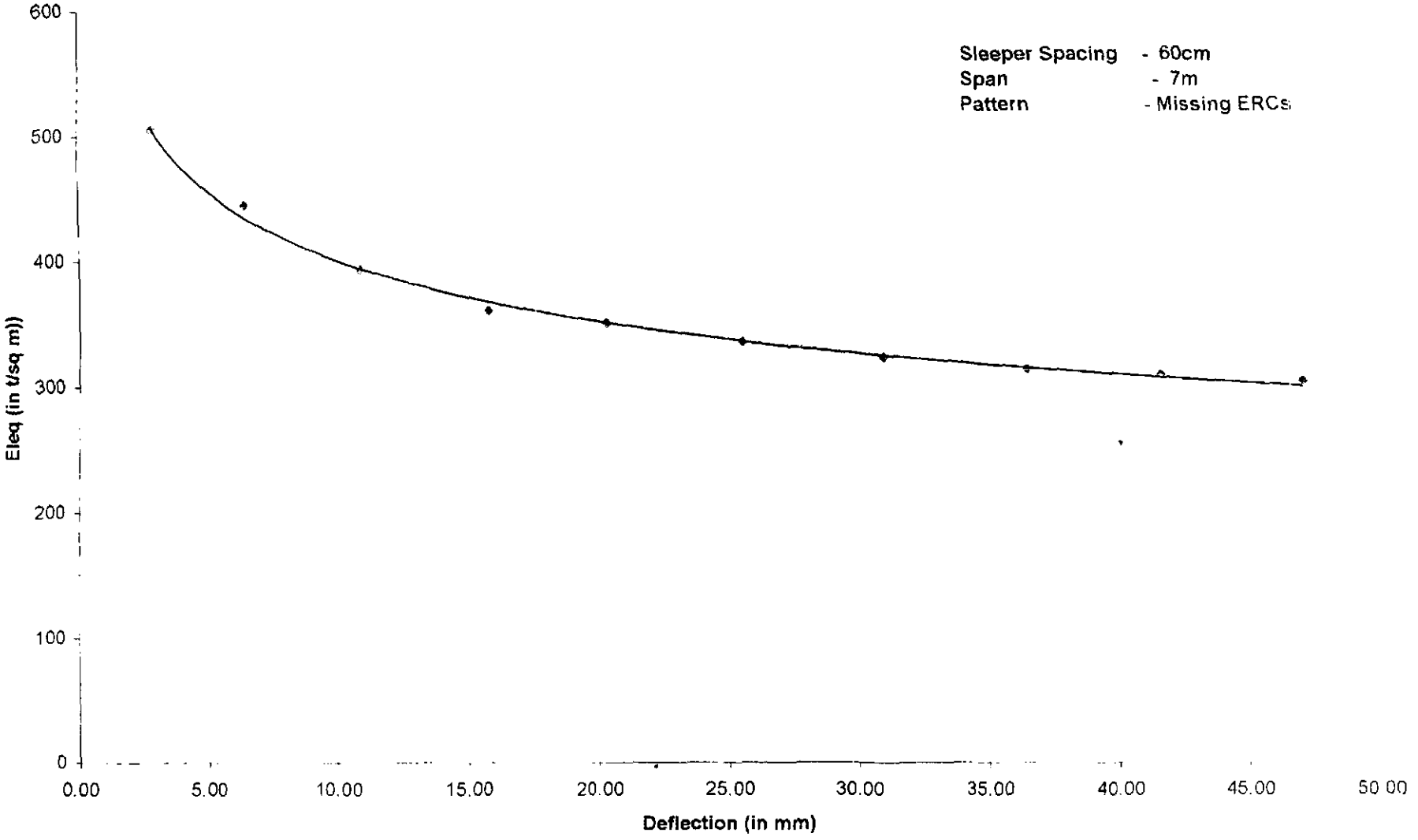
Graph 14A : Load Vs Deflection



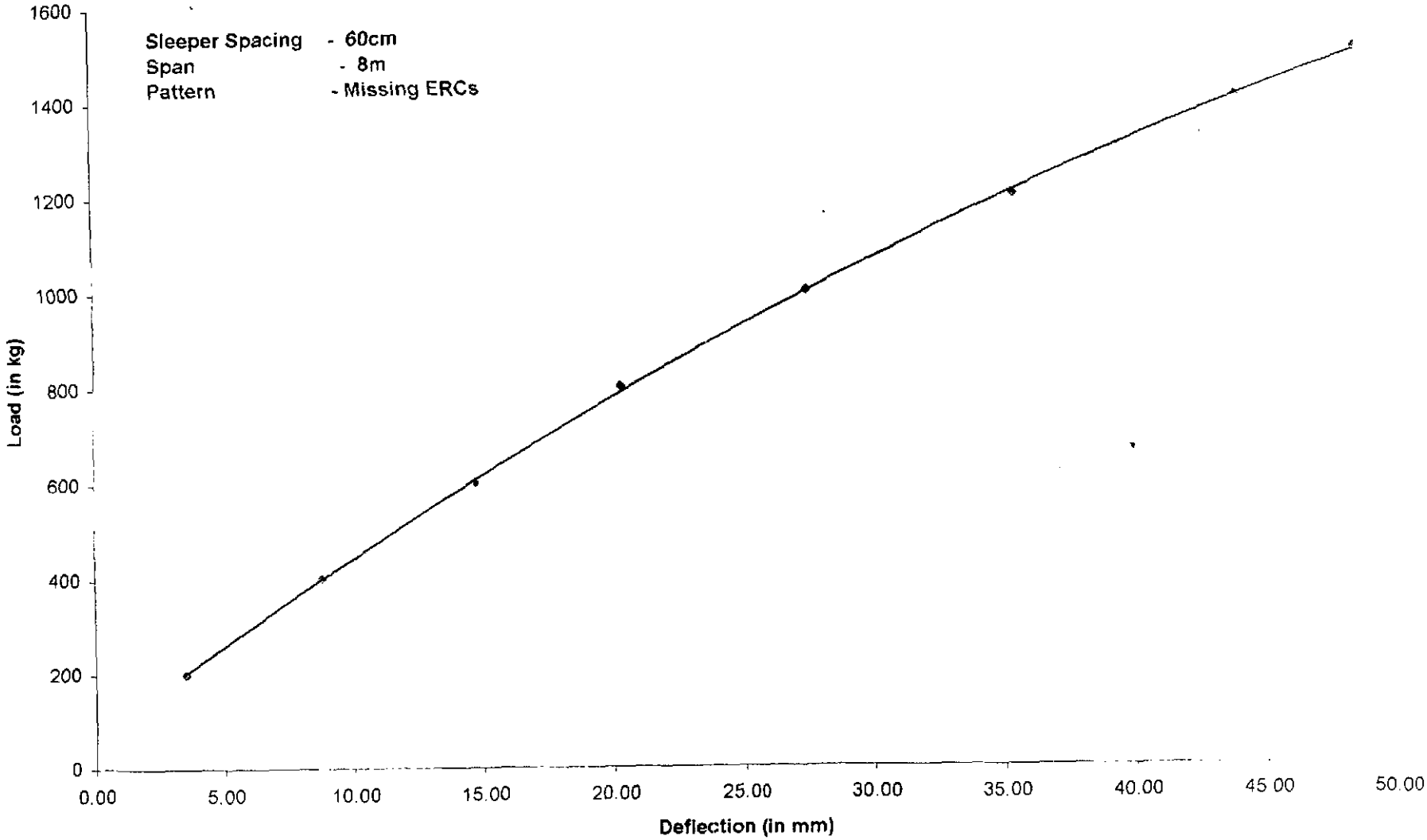
Graph 14B : Deflection Vs Eleq



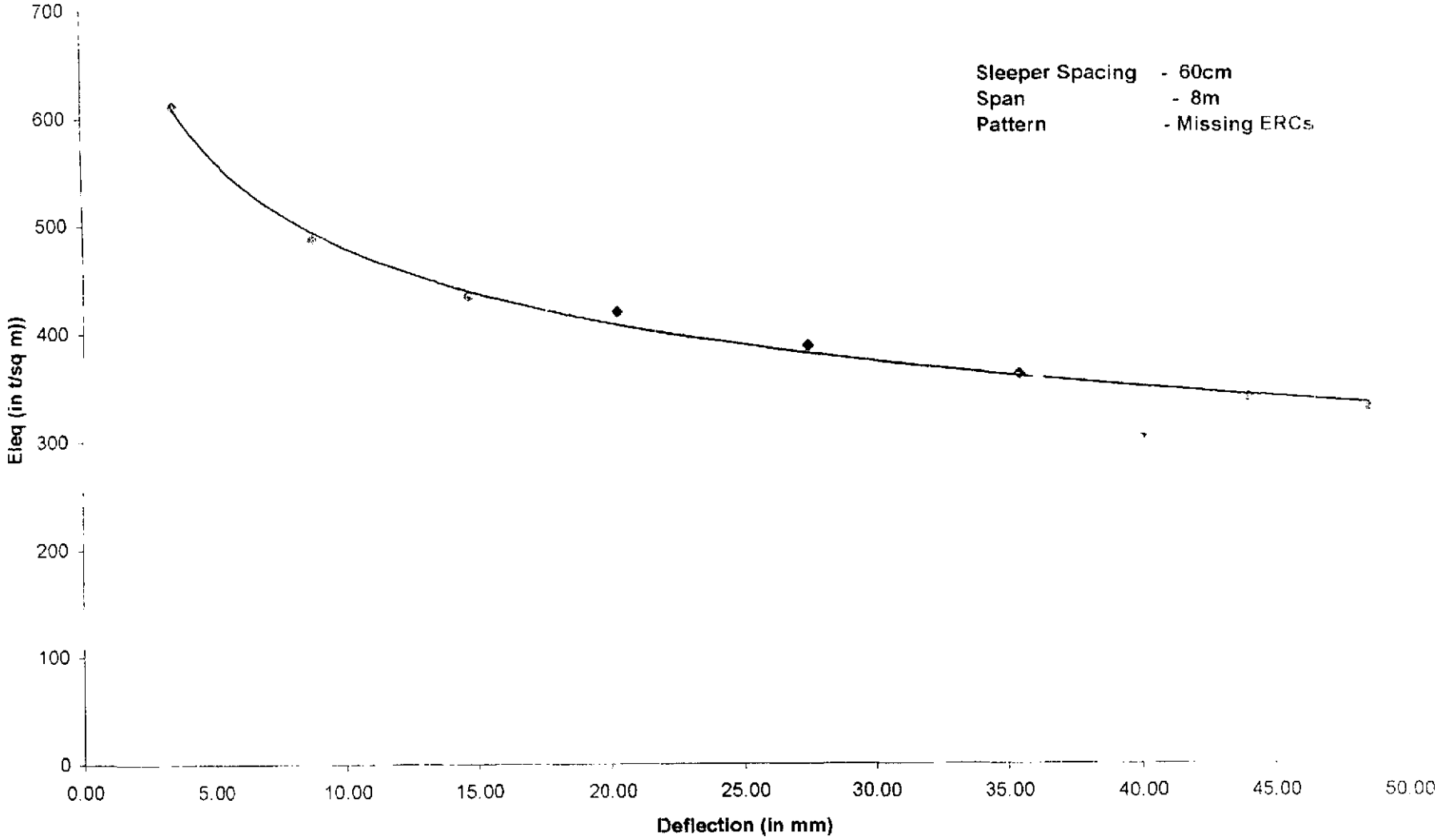
Graph 15A : Load Vs Deflection



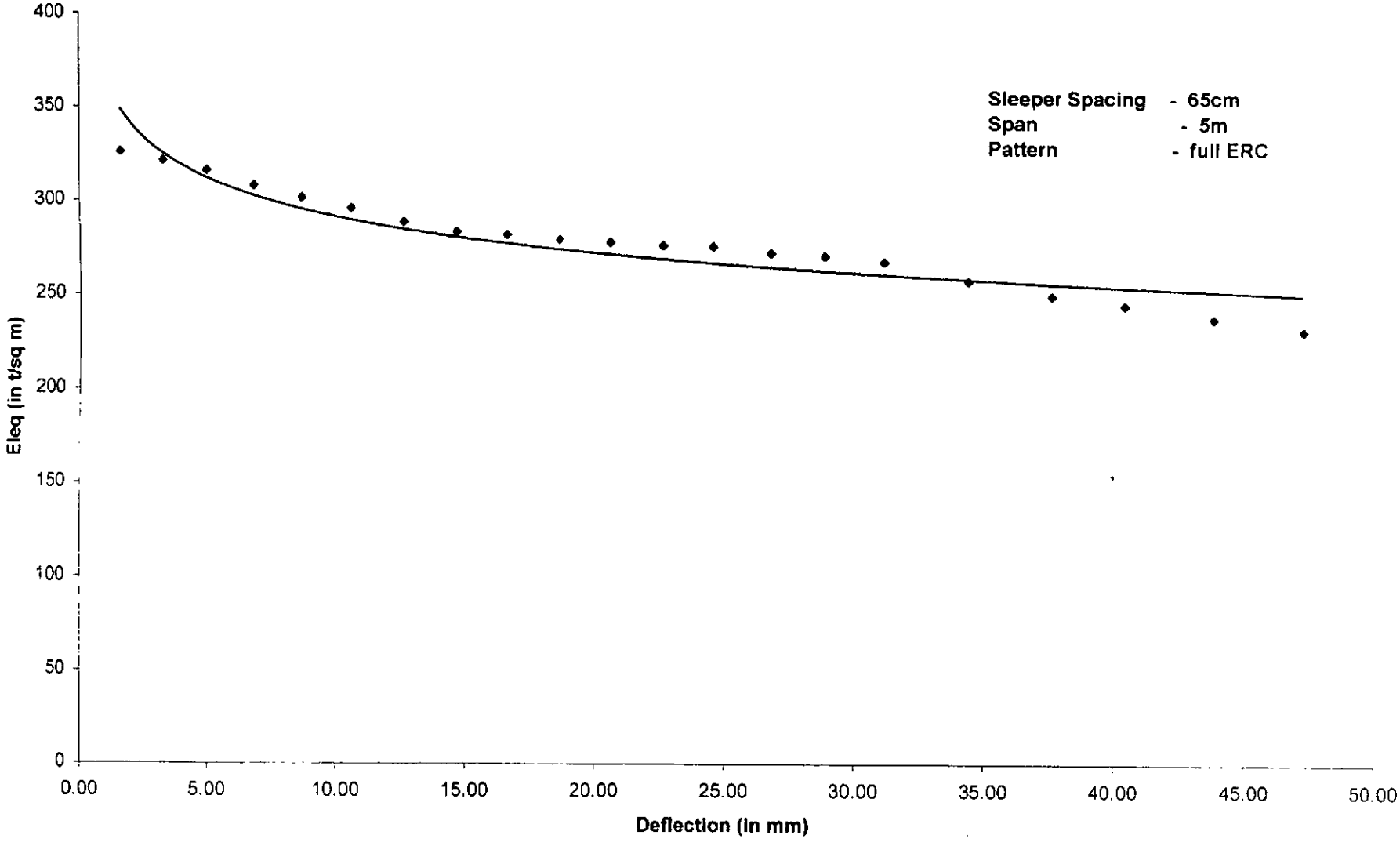
Graph 15B :Deflection Vs Eleq



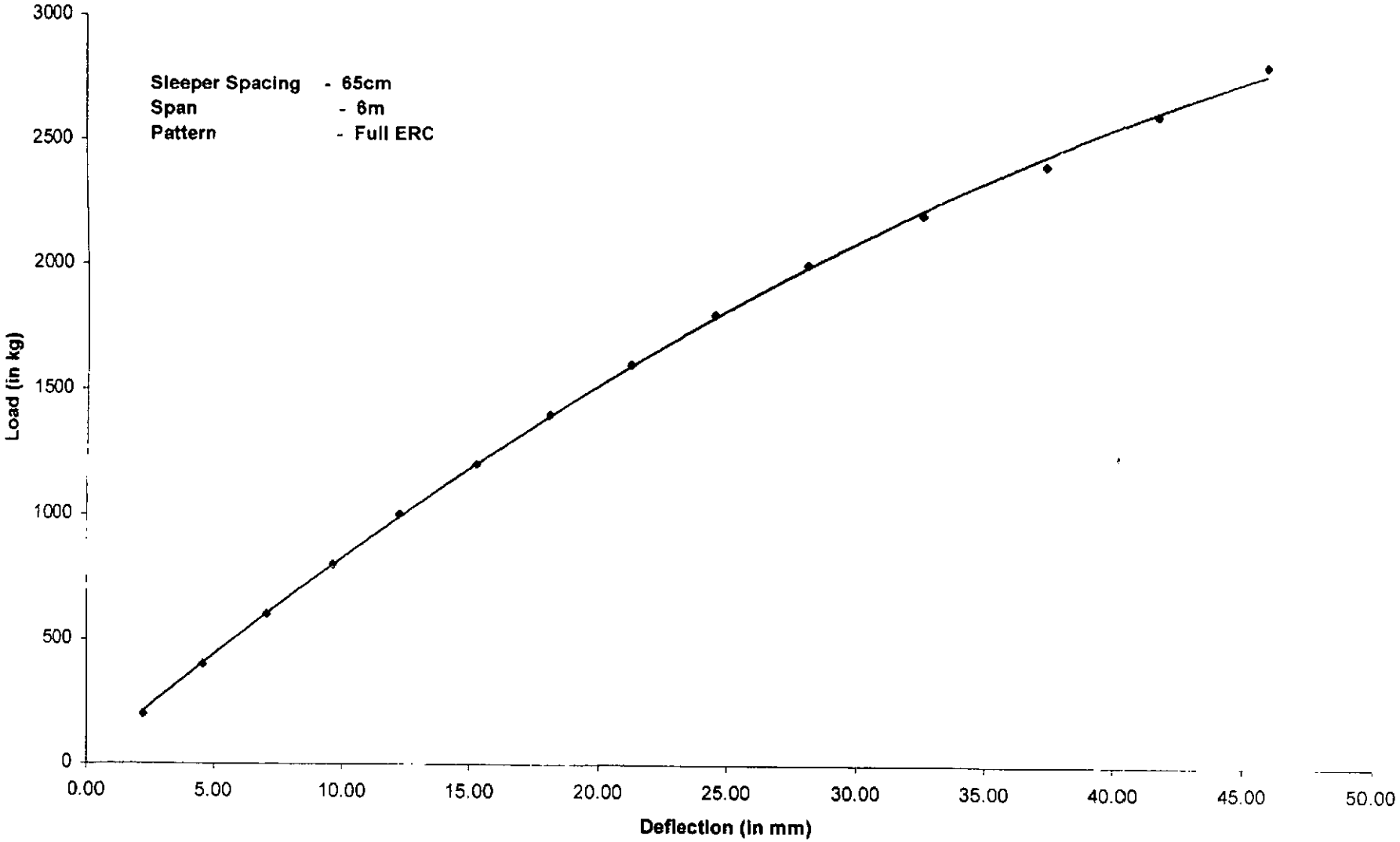
Graph 16A : Load Vs Deflection



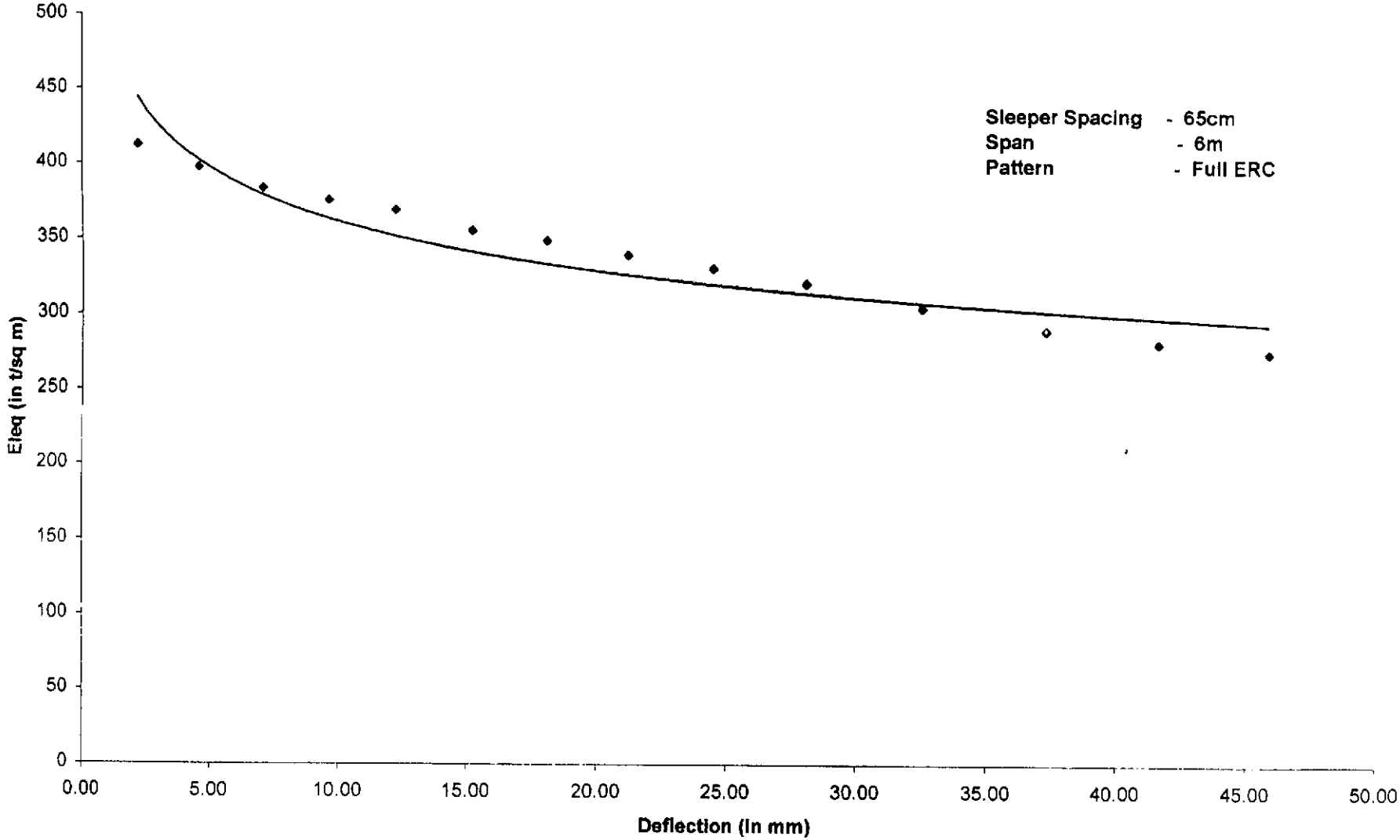
Graph 16B : Deflection Vs Eleq



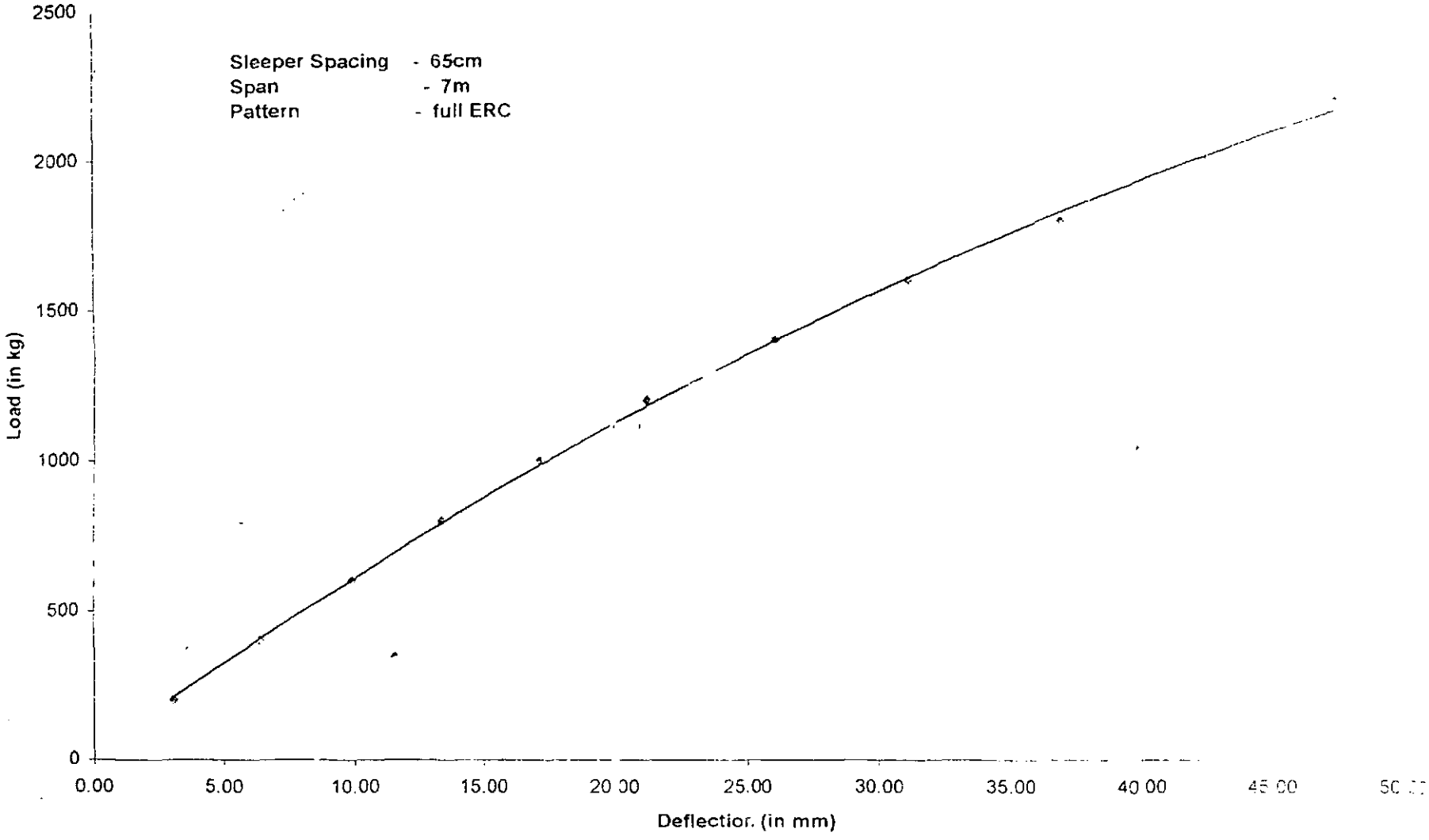
Graph 17B : Deflection Vs Eleq



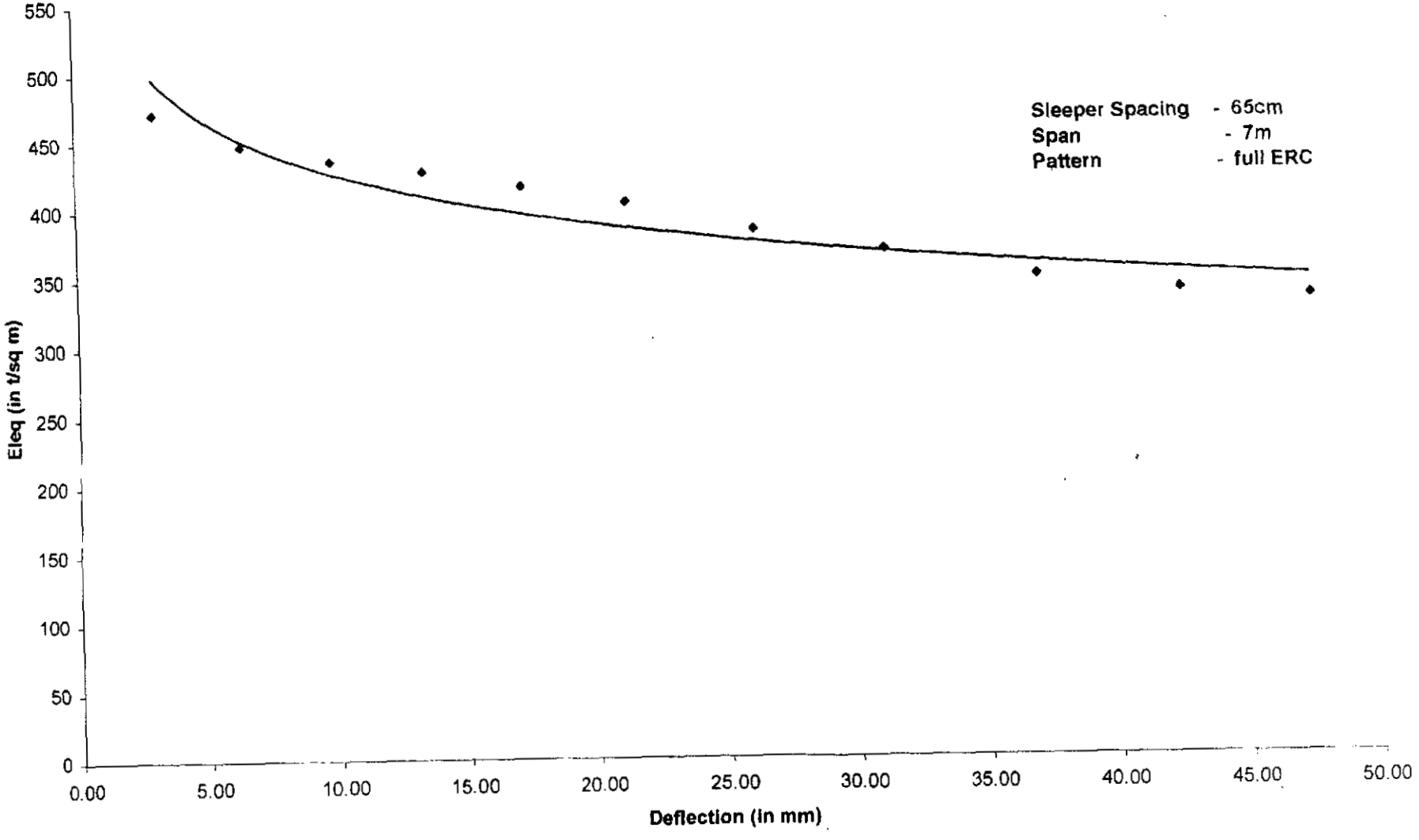
Graph 18A : Load Vs Deflection



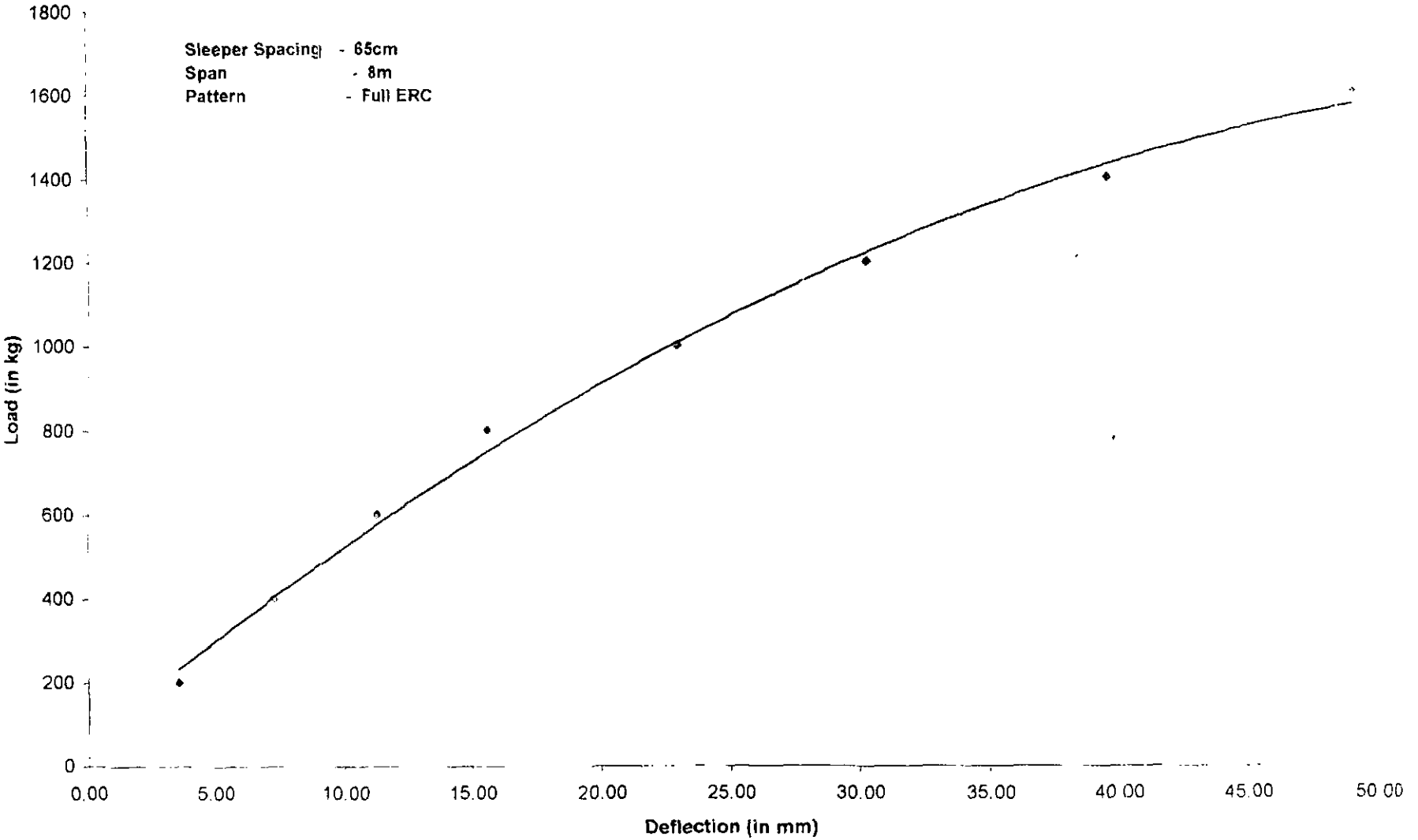
Graph 18B : Deflection Vs Eleq



Graph 19A : Load Vs Deflection

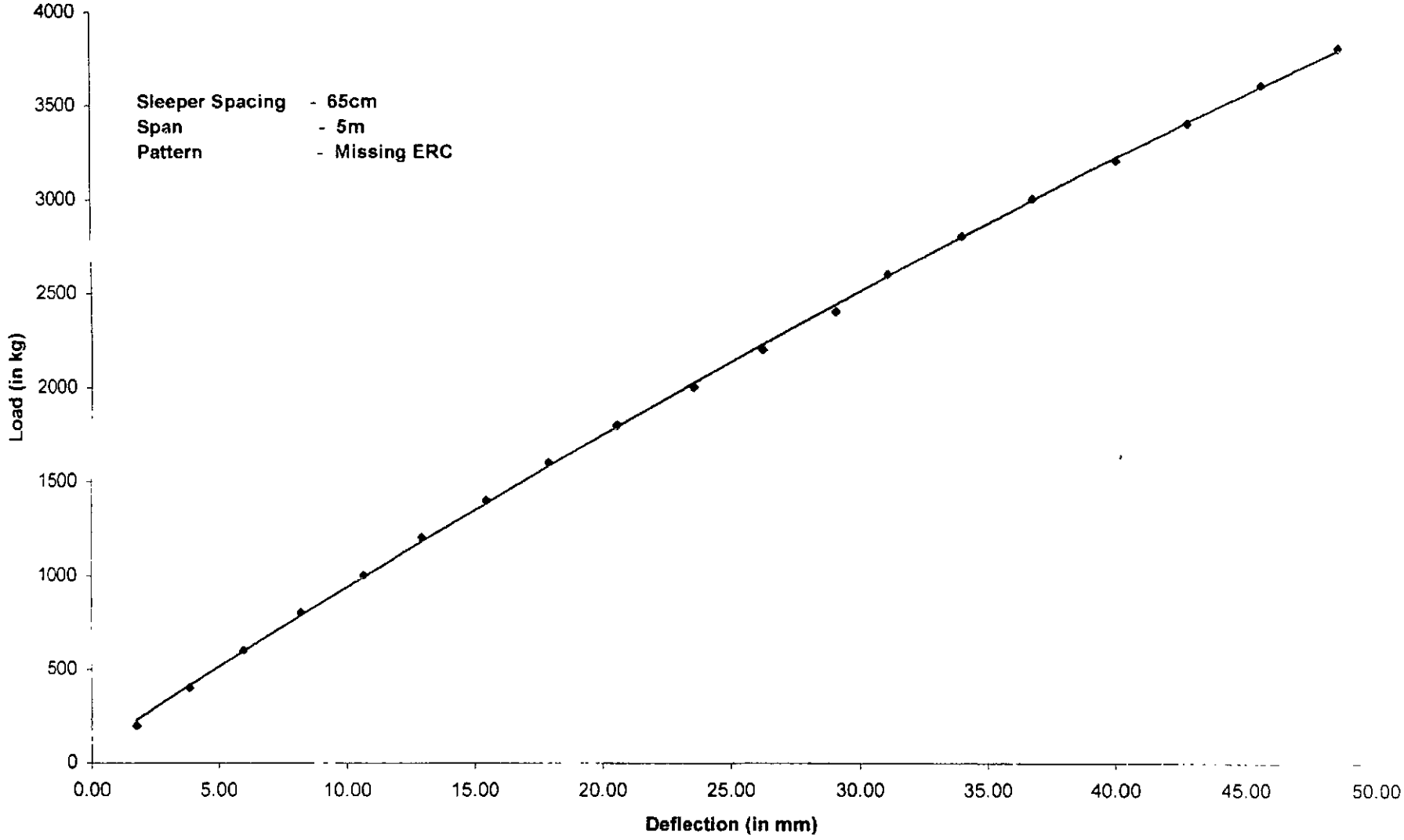


Graph 19B : Deflection Vs Eleq

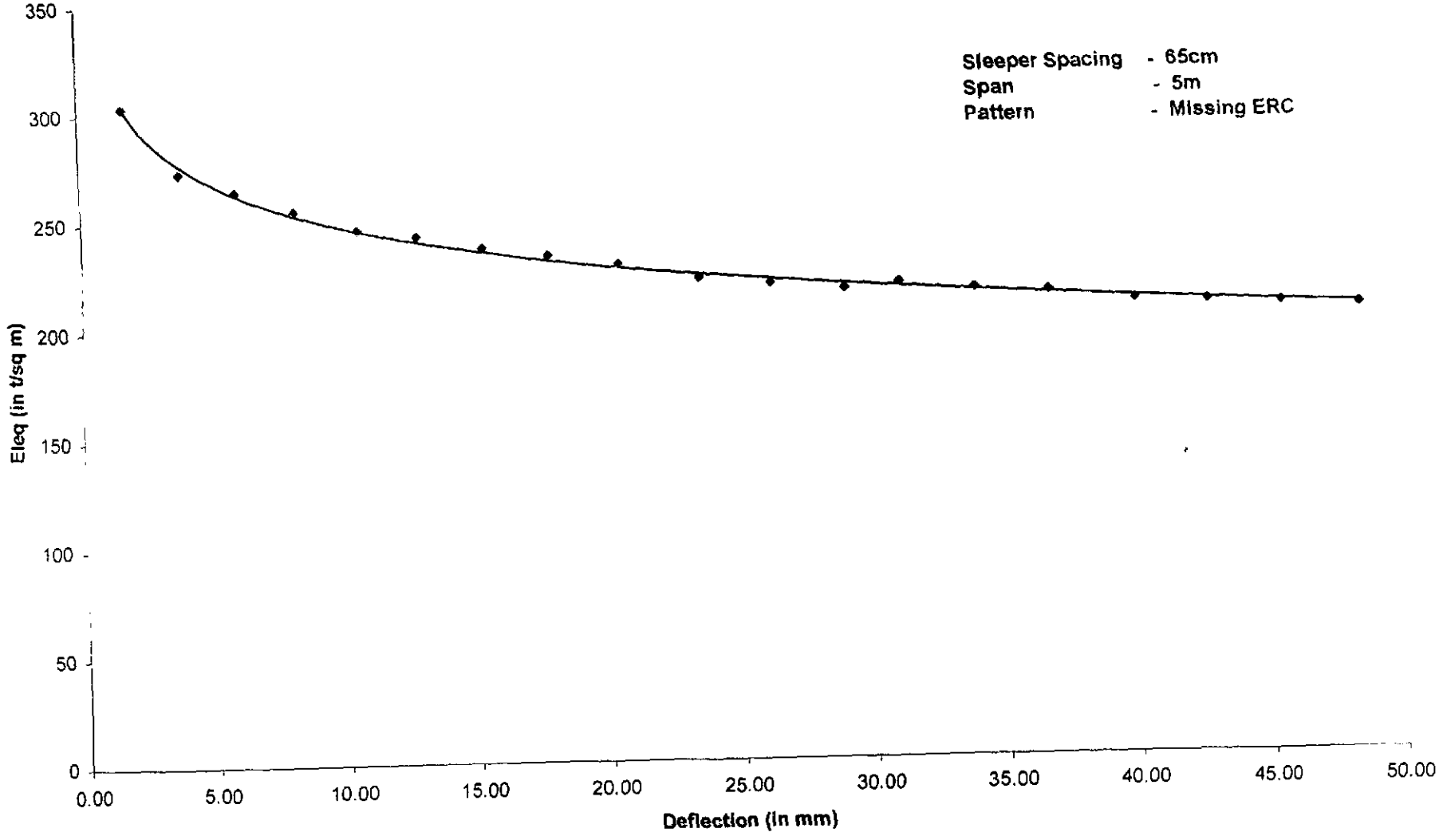


Graph 20A : Load Vs Deflection

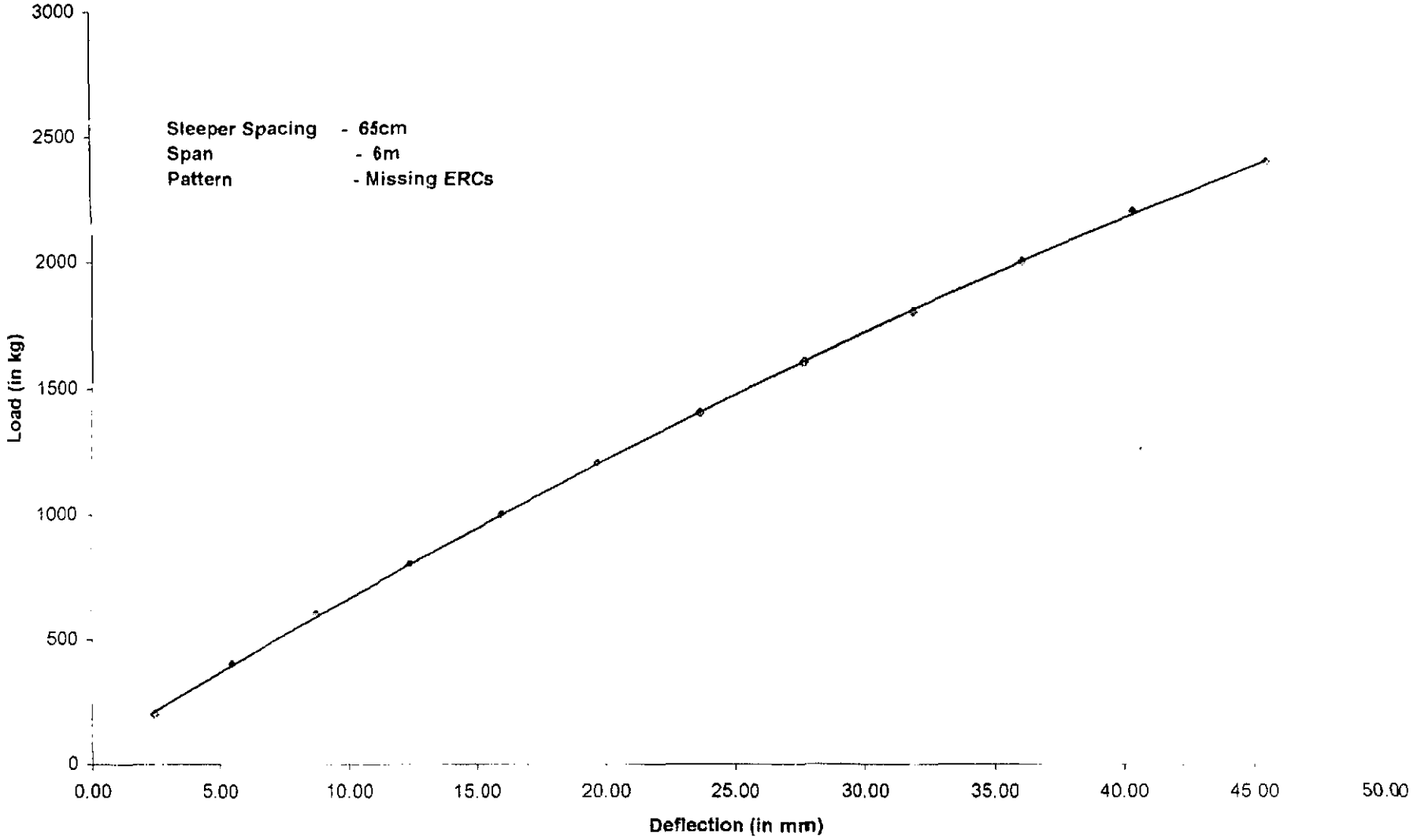
05379



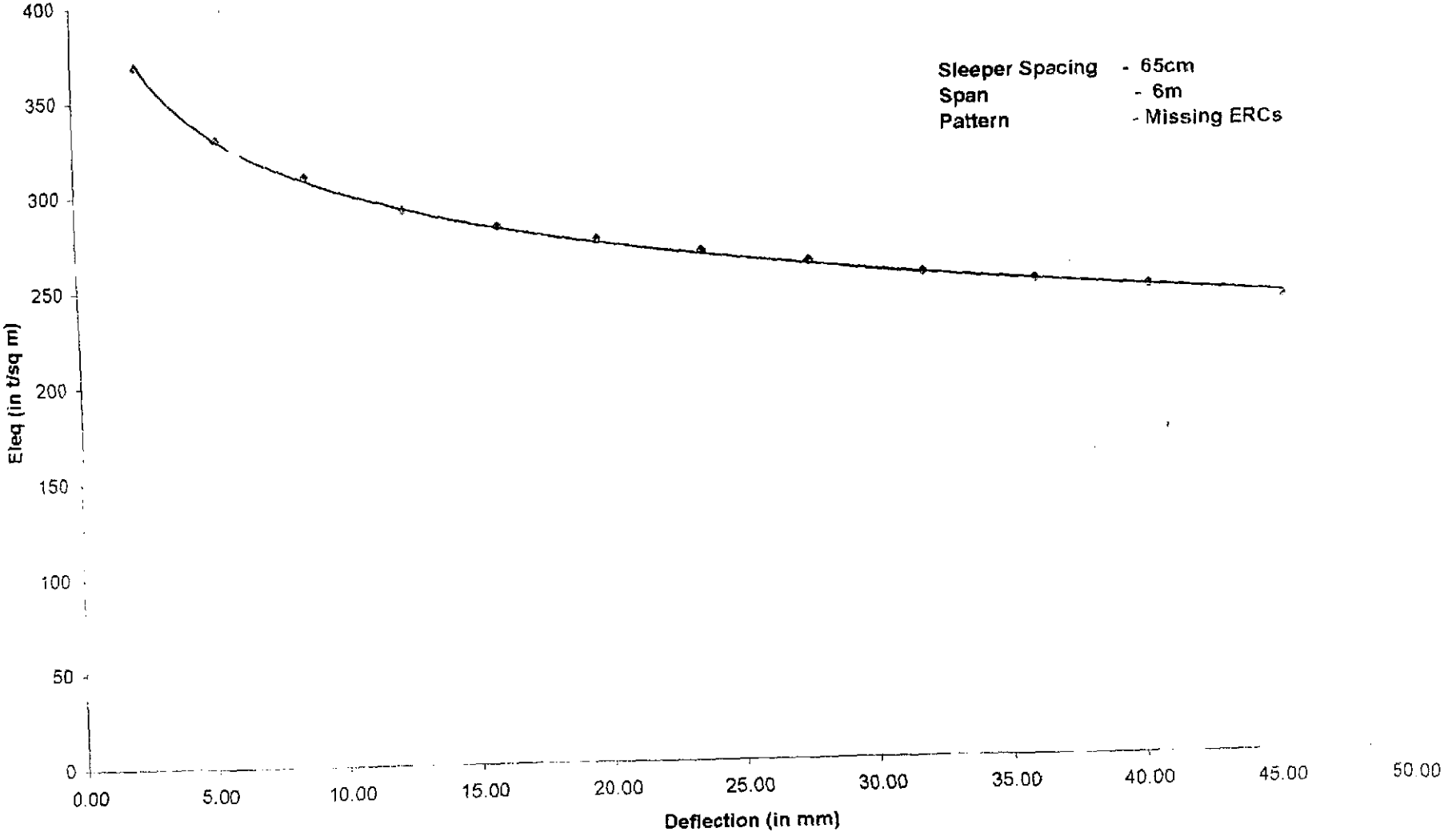
Graph 21A : Load Vs Deflection



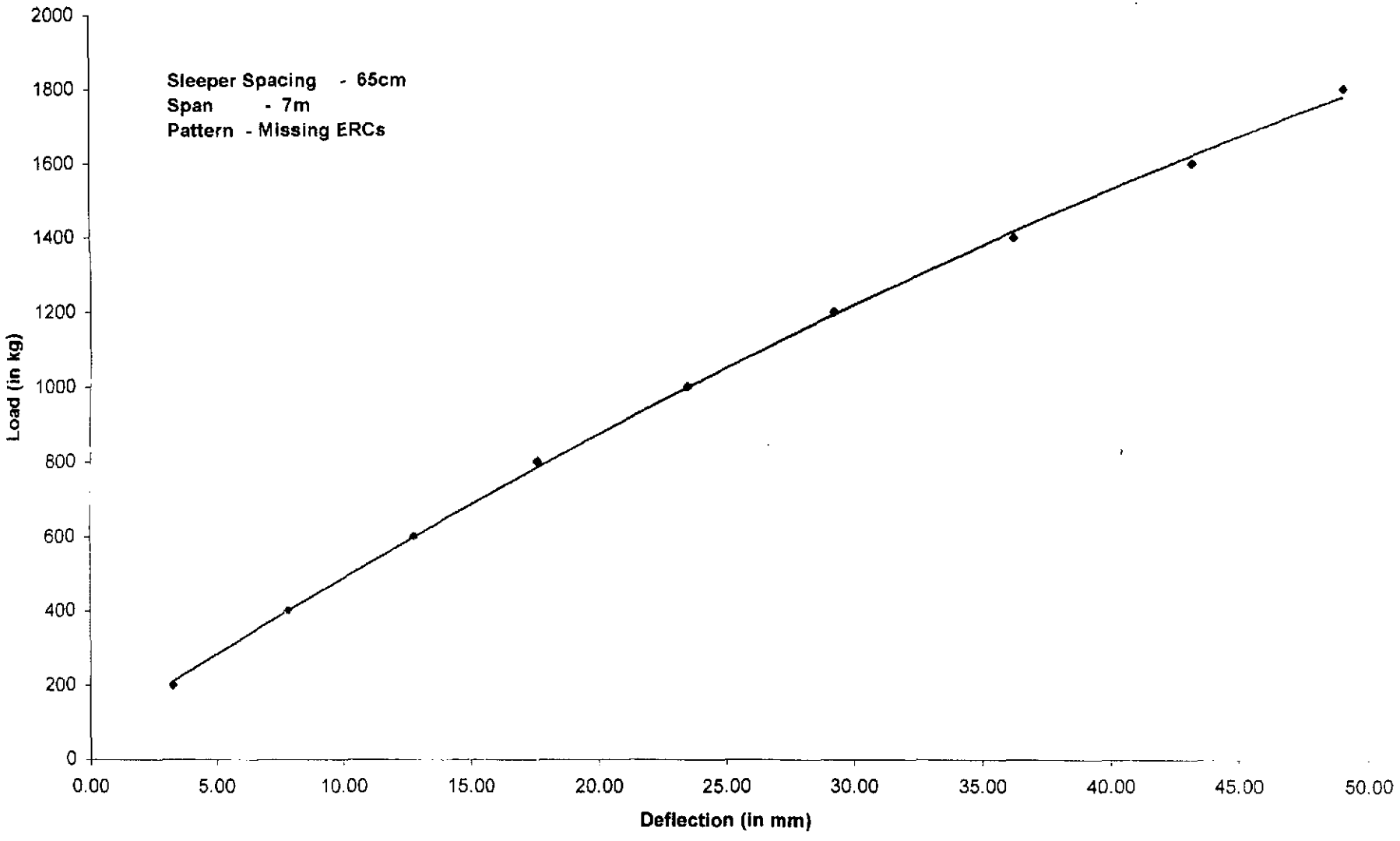
Graph 21B : Deflection Vs Eleq



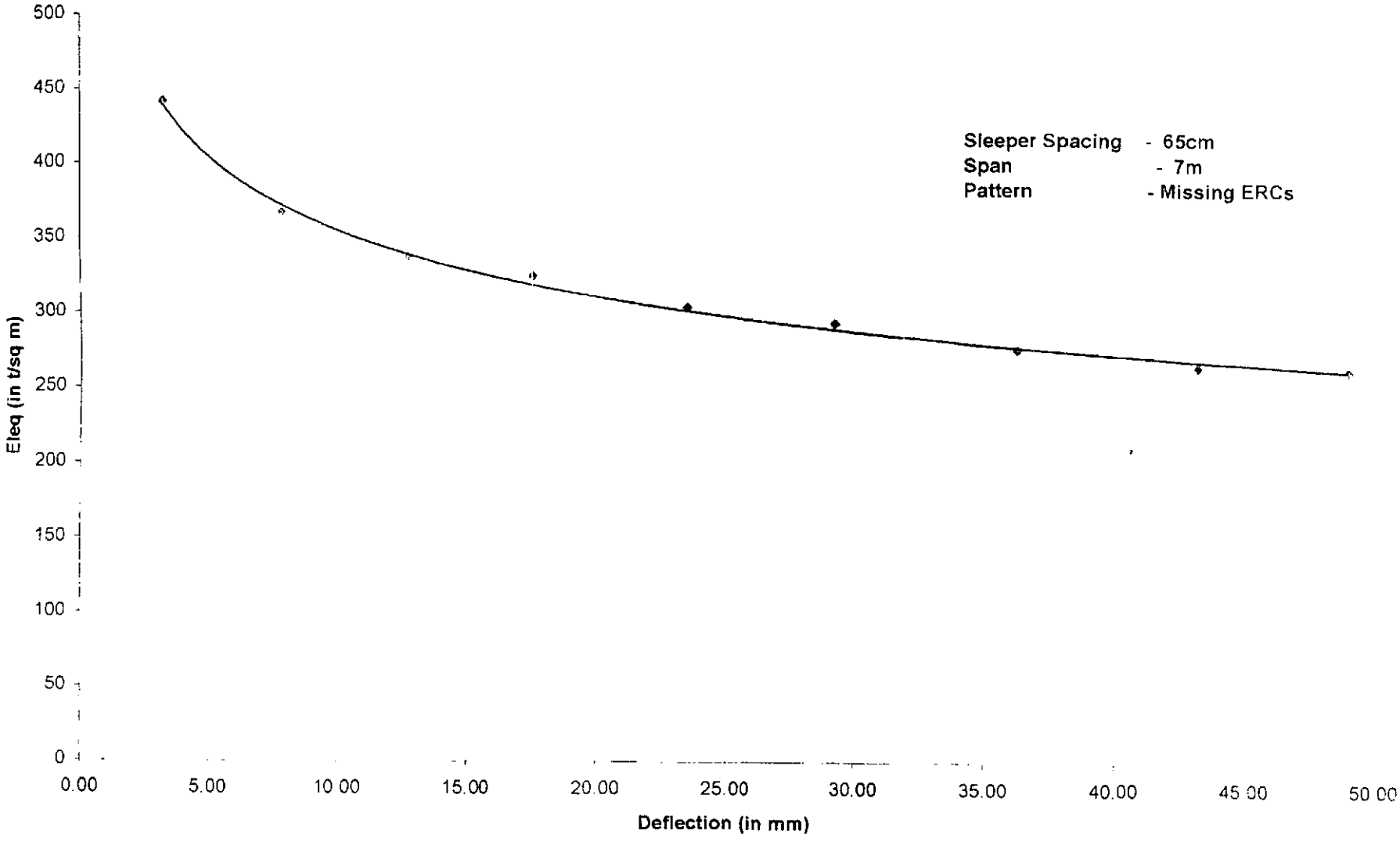
Graph 22A : Load Vs Deflection



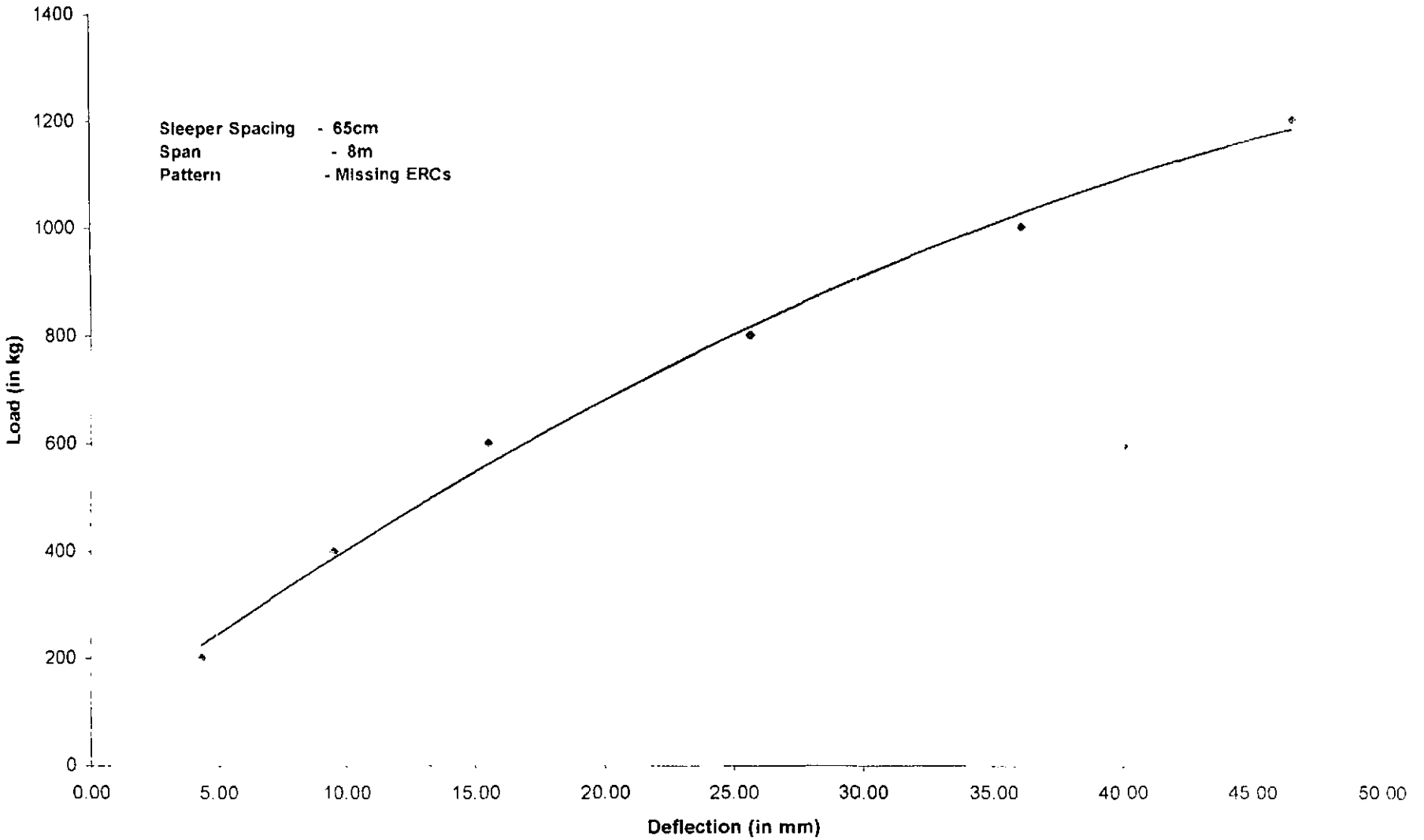
Graph 22B : Deflection Vs Eleq



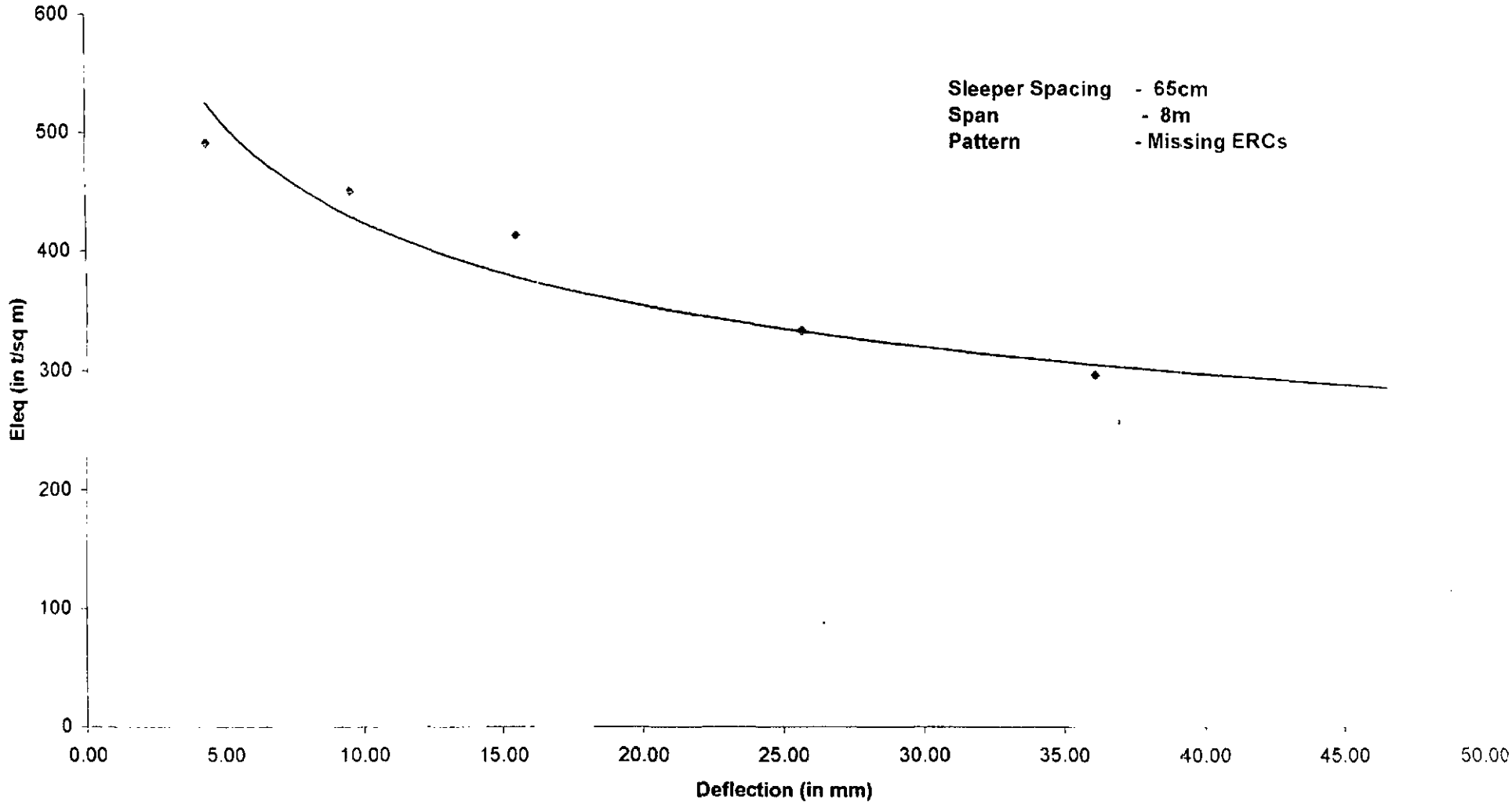
Graph 23A : Load Vs Deflection



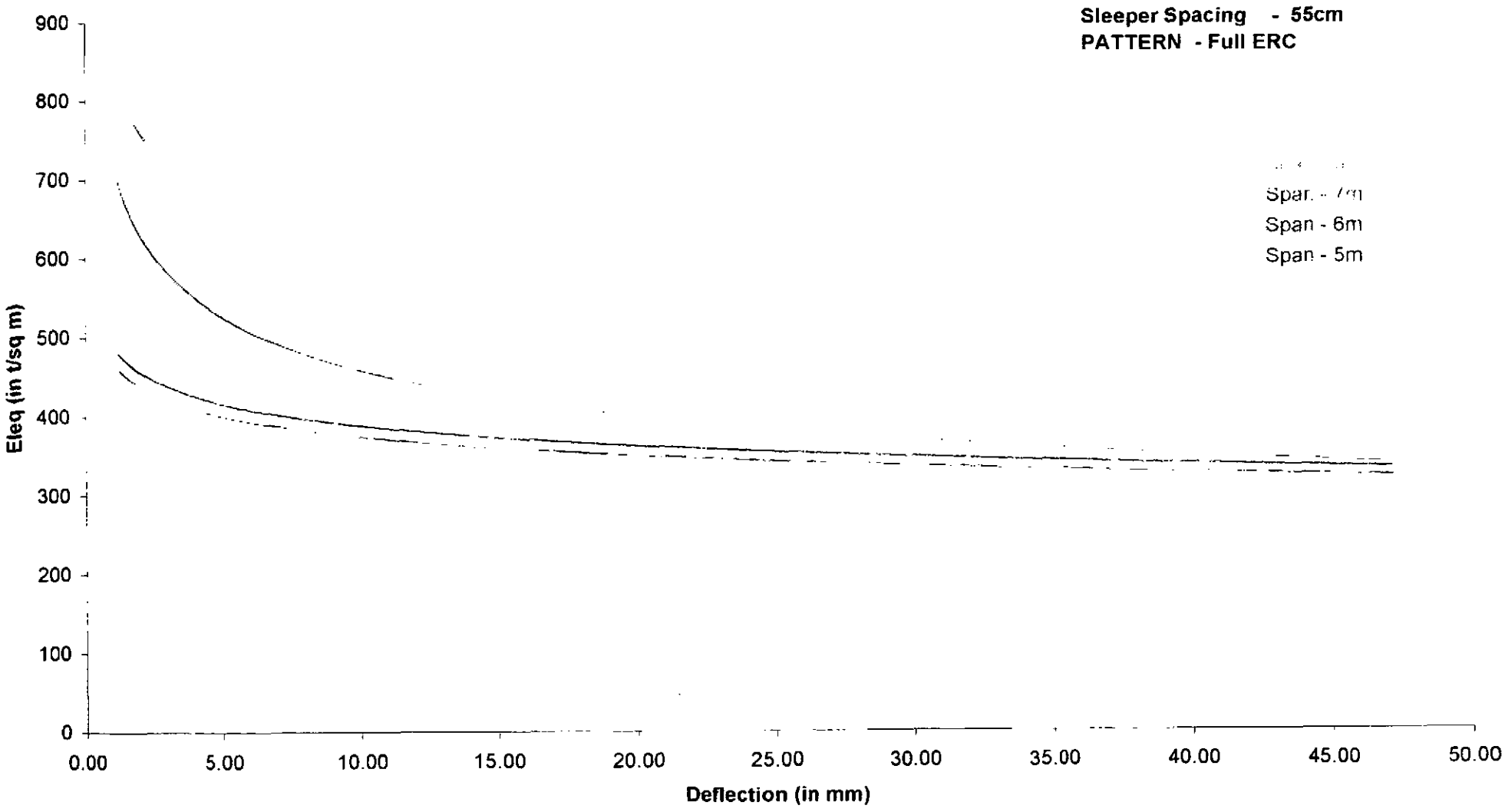
Graph 23B : Deflection Vs Eleq



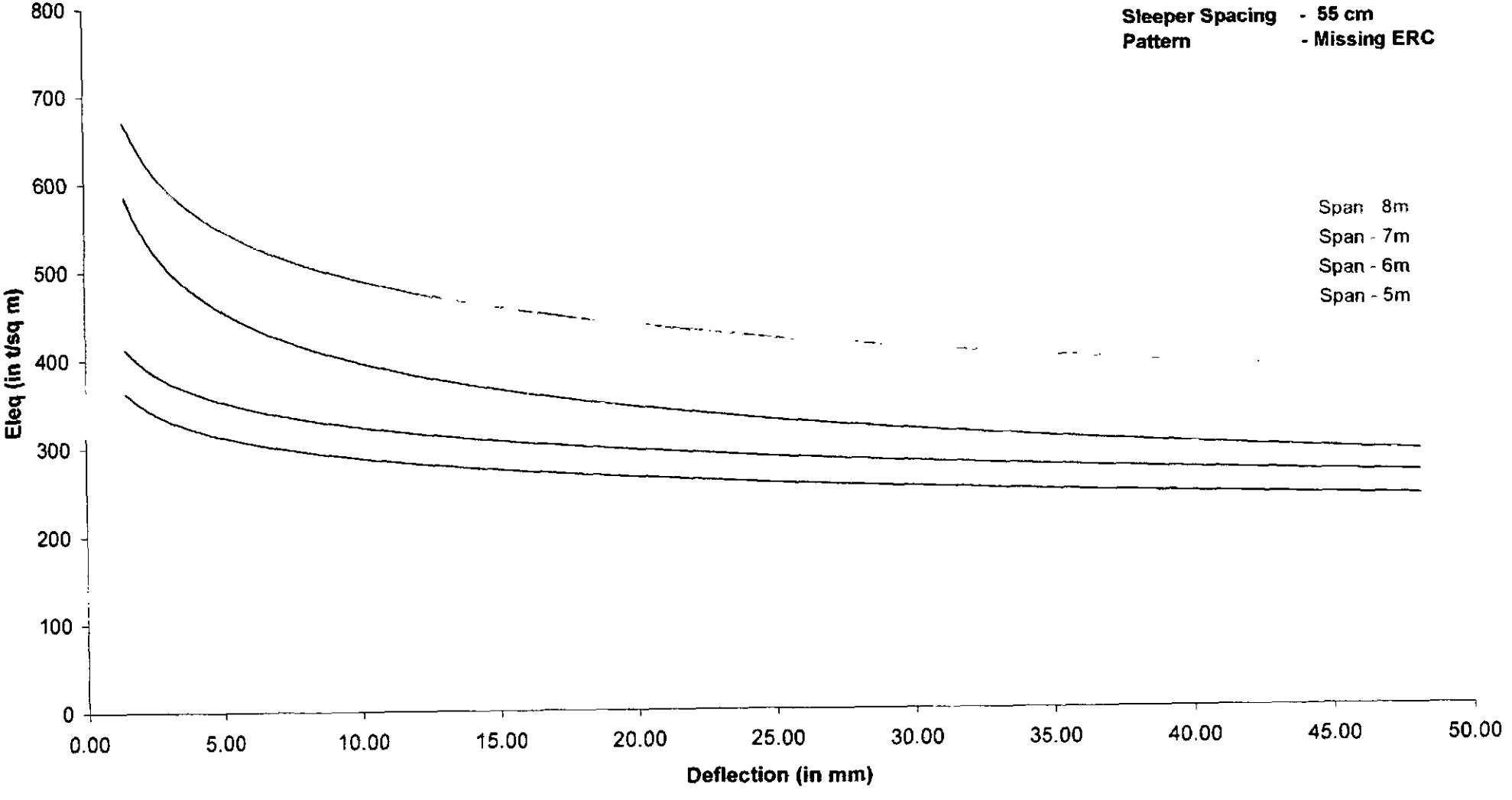
Graph 24A : Load Vs Deflection



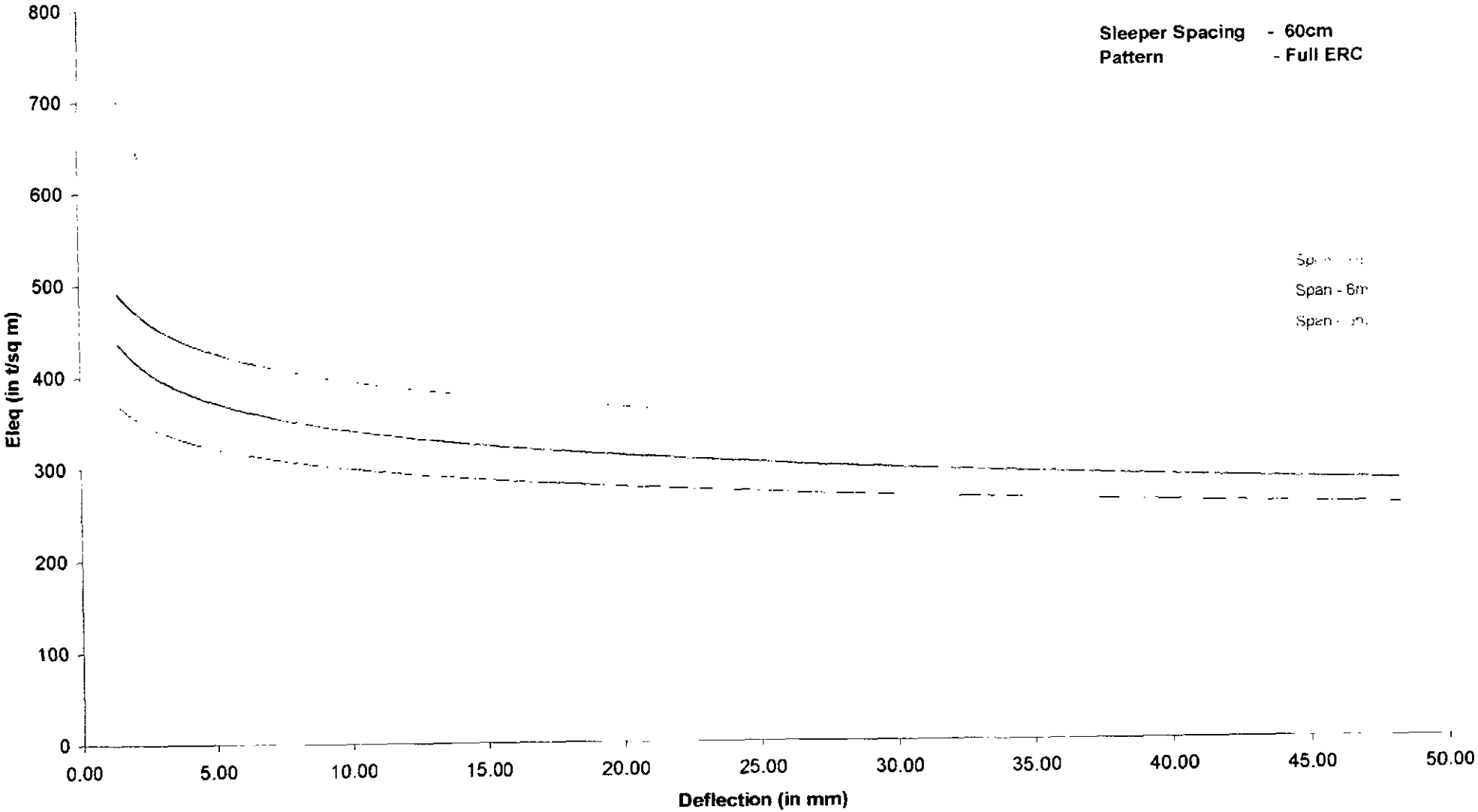
Graph 24B : Deflection Vs Eleq



Graph-I : Deflection Vs Eieq for different spans on sleeper spacing 55 cm

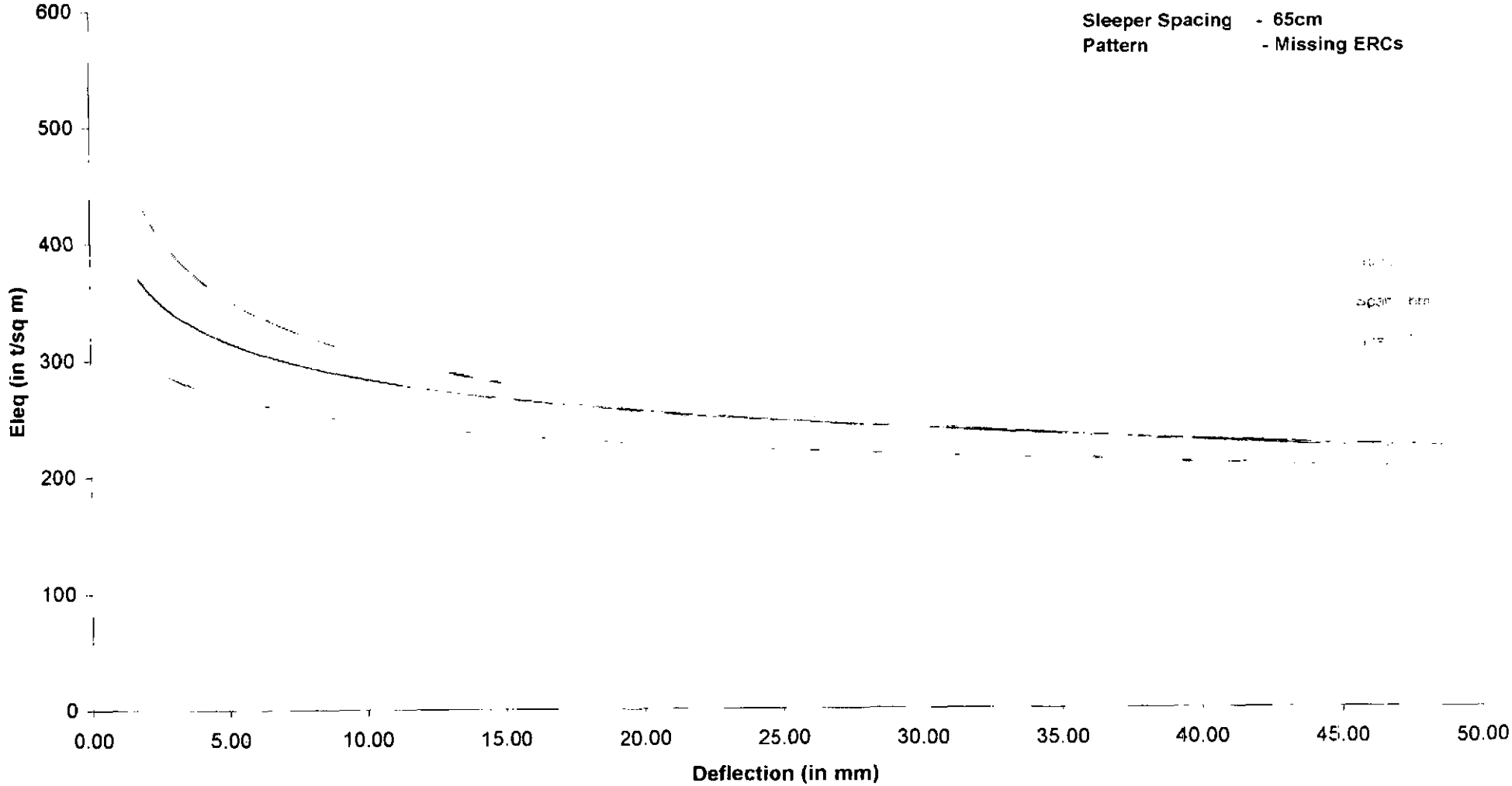


Graph-II : Deflection Vs Eleq for different spans on sleeper spacing 55 cm(missing ERC pattern)

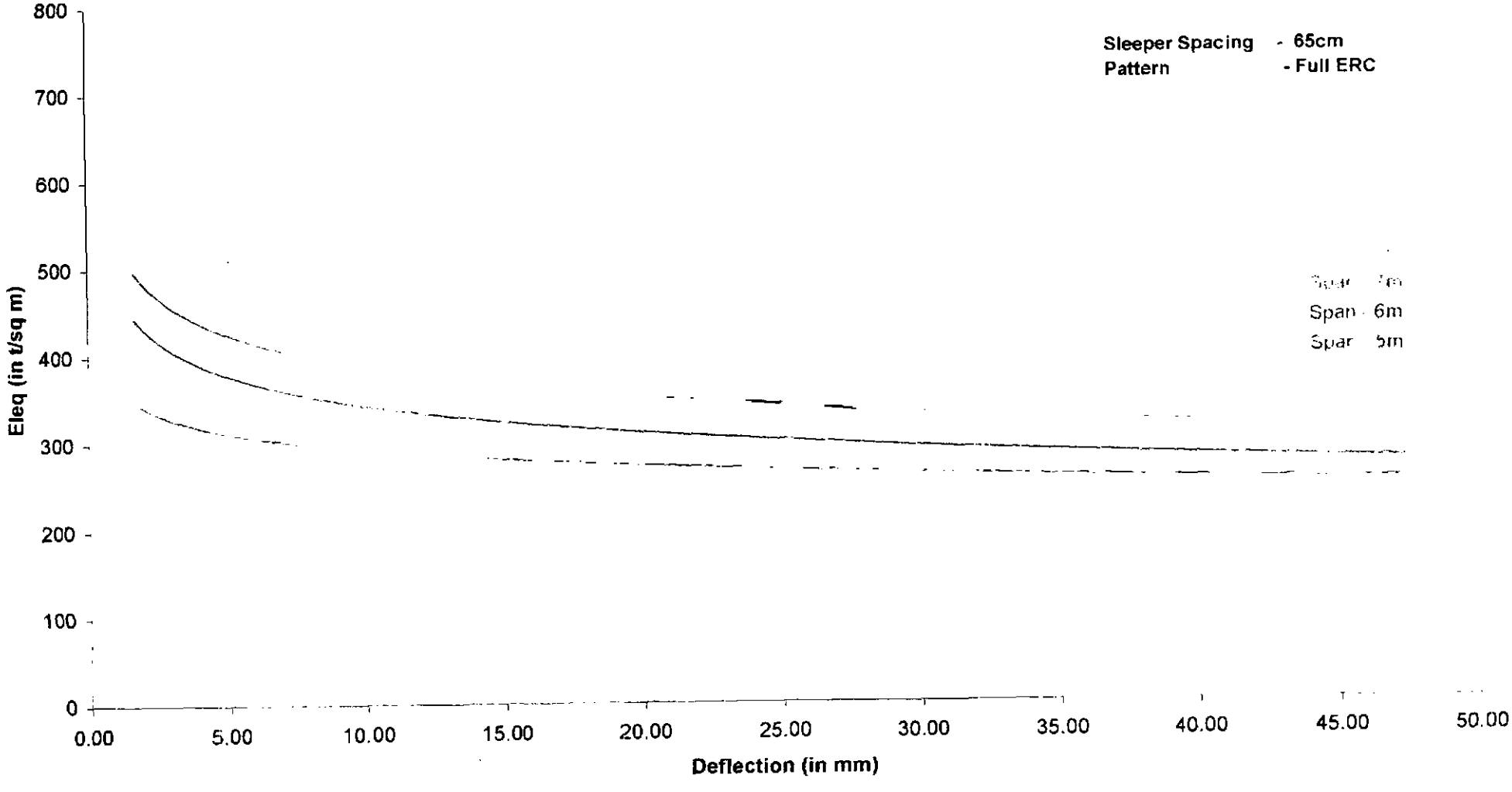


Graph-III: Deflection Vs Eleq for different spans on sleeper spacing 60 cm

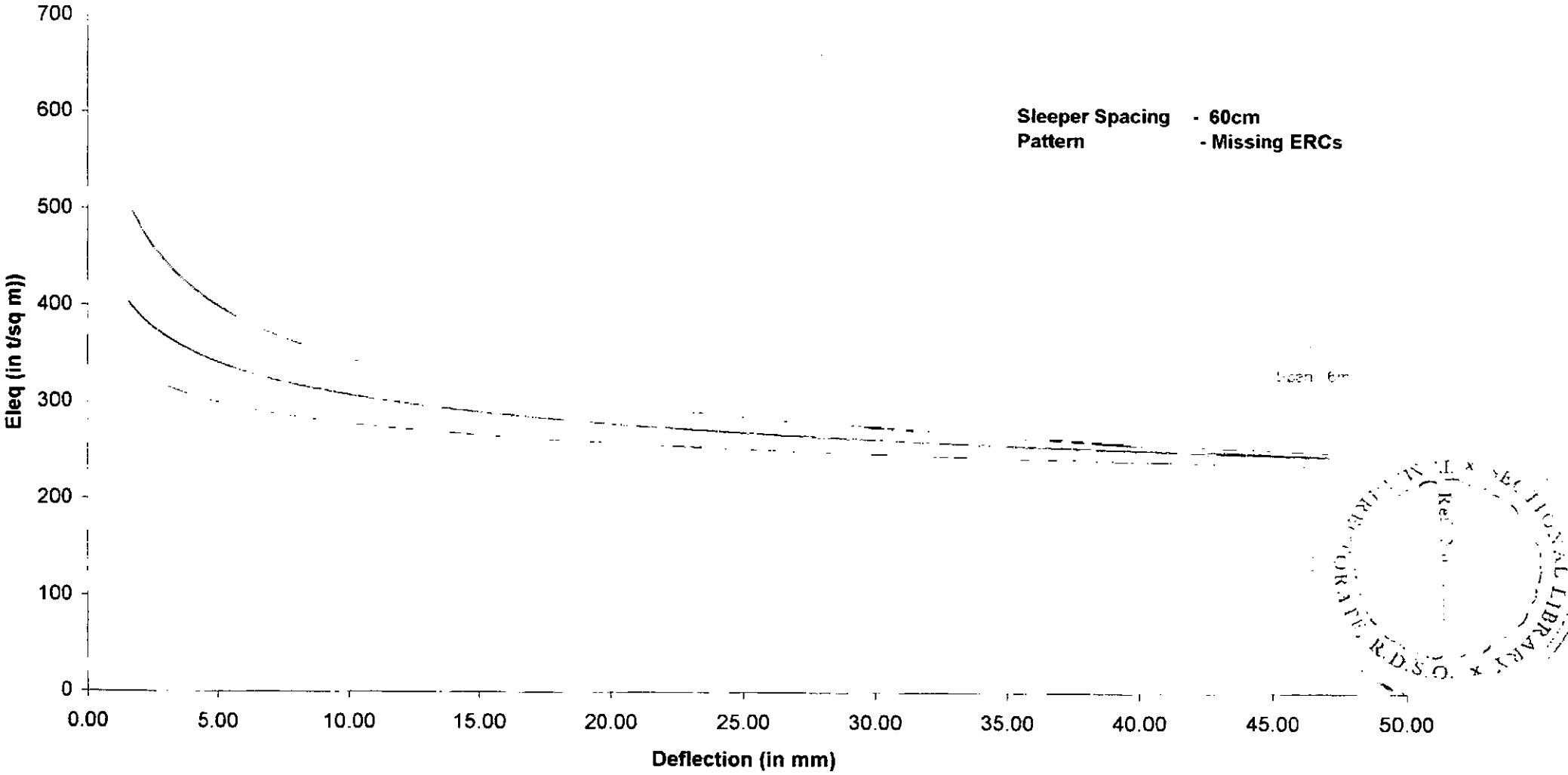
05391



Graph-VI : Deflection Vs Eleq for different spans on sleeper spacing 65 cm



Graph-V : Deflection Vs Eleq for different spans on sleeper spacing 65 cm



Graph-IV : Deflection Vs Eleq for different spans on sleeper spacing 60 cm

This report is based on the investigations conducted by a team consisting of following officers and staff under the guidance of Sri P.K.Garg Director/TM-III

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4. Sri Ramagyan Pd.	-	SE/Engg.
5. Sri Ashok Kr.	-	SSRE/Instt.
6. Sri Ajay Singh	-	JRE/I-Instt.
7. Sri Aqil Mohsin	-	JE/II-Mech.
8. Sri R.P.S.Payal	-	TG-I
9. Sri Nankoo	-	TG-I
10.Sri Gayadeen	-	TG-III
11.Sri B.S.Chauhan	-	TG-III
12.Sri P.N. Mishra	-	TG-III