Can a Heavy Falling Weight Deflectometer Improve Construction Control? – A case study

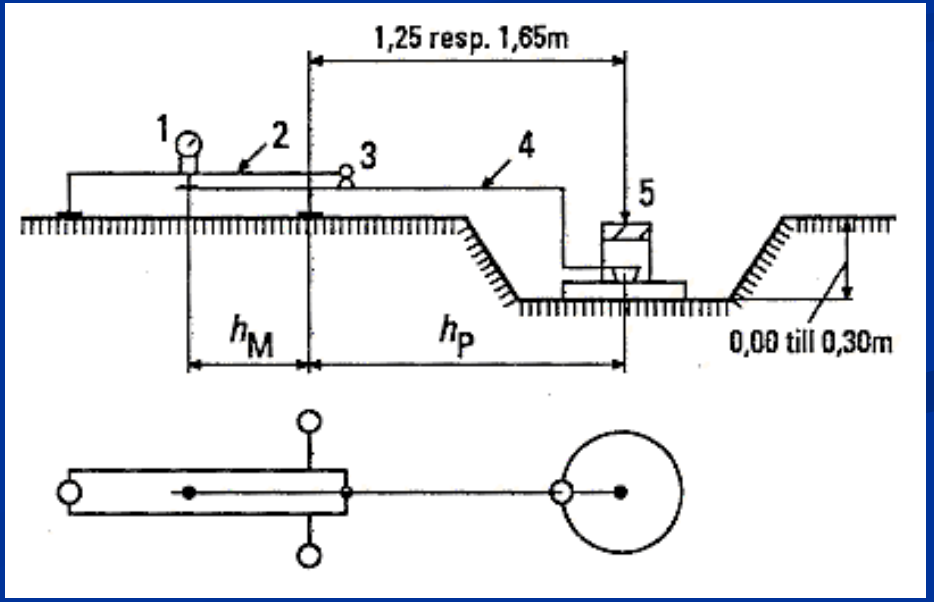
Carl A. Lenngren

Swedish Road Administration

Consulting Services

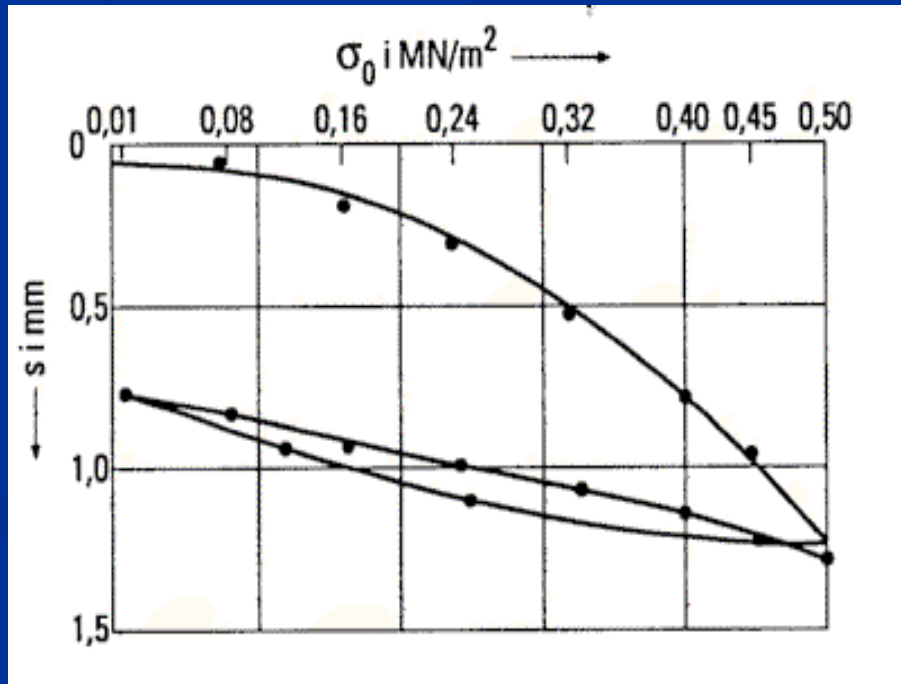
Background

- The Static Load Plate (SLP) test is commonly used for construction control on unbound surfaces.
  - Surface modulus > 60 Mpa



Background

- The Static Load Plate (SLP) test is commonly used for construction control on unbound surfaces.
- Compaction : Ev2/Ev1 > 1.2



Background

- At a construction site (bridge embankment) the Contractor was unable to meet specifications!

Objekt: Nr 133416 **E6 Värmlandsbro - Hogdal**	**Provtagningsdatum:** **2008-03-07**	**Provtagare:** **VV/KUNGÄLV/LAB AMIR RAJABI**
Beställare(enhet): **VV-Produktion**	**Märkning:** **BRO O1792**	**Underlag:** **Bärlager**

SAMMANSTÄLLNING AV PLATTBELASTNING MÄTRESULTAT

NR	SEKTION	EV1 (MN/m^2)	EV2 (MN/m^2)	EV2/EV1	
1	NORRA SIDAN p1	19,21	43,89	2,28	
2	NORRA SIDAN p2	23,18	53,49	2,31	
3	NORRA SIDAN p3	21,65	48,68	2,24	
4	SÖDRA SIDAN P4	40,81	67,38	1,65	
5	SÖDRA SIDAN P5	36,45	84,79	2,33	
6	SÖDRA SIDAN P6	44,31	71,92	1,62	

Reason for failure

- 3 of 6 values failed Static Plate Load Test, should be > 60 Mpa

However:

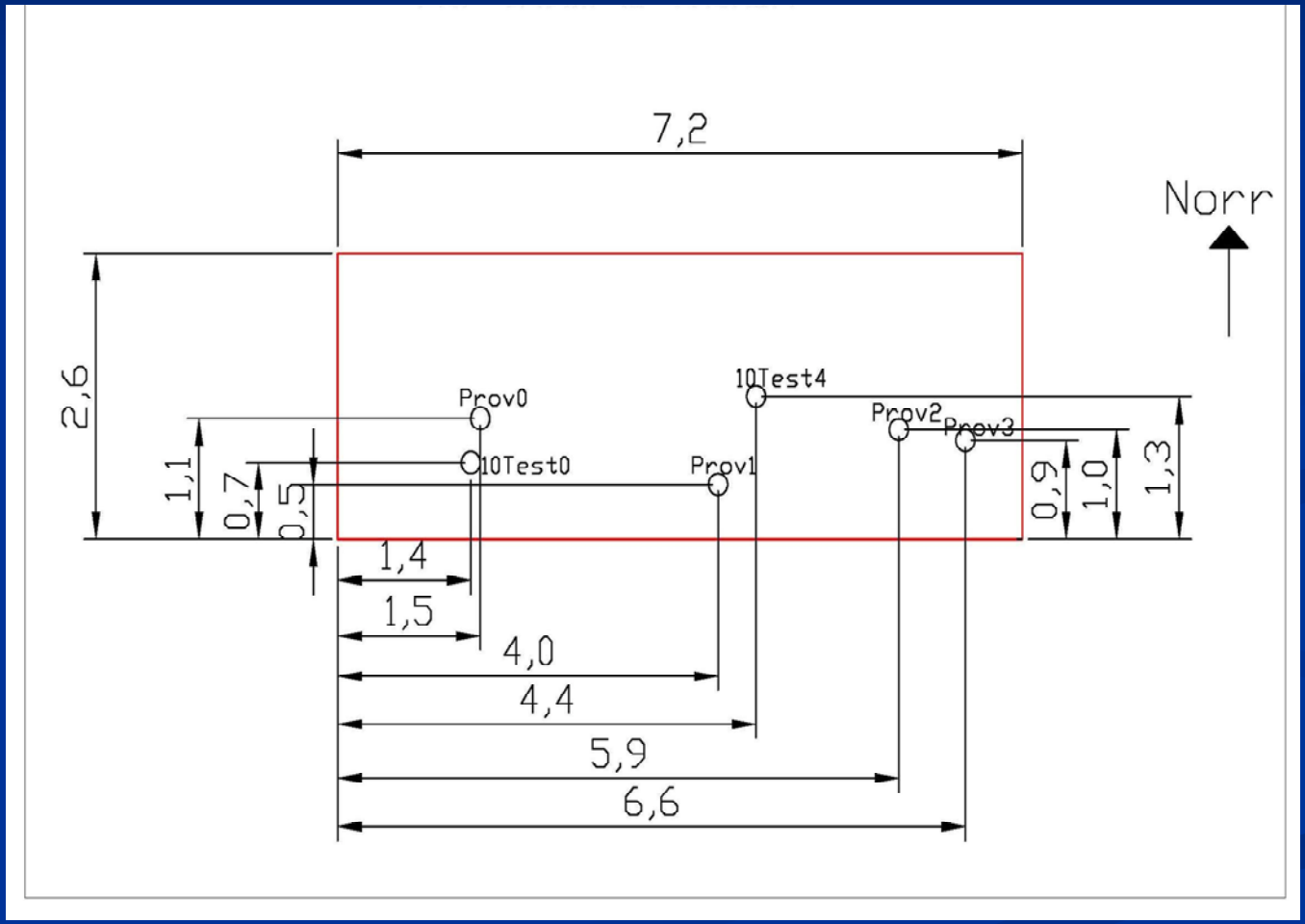
- Light FWD:s are allowed as an alternative to SLP.

Reason for failure

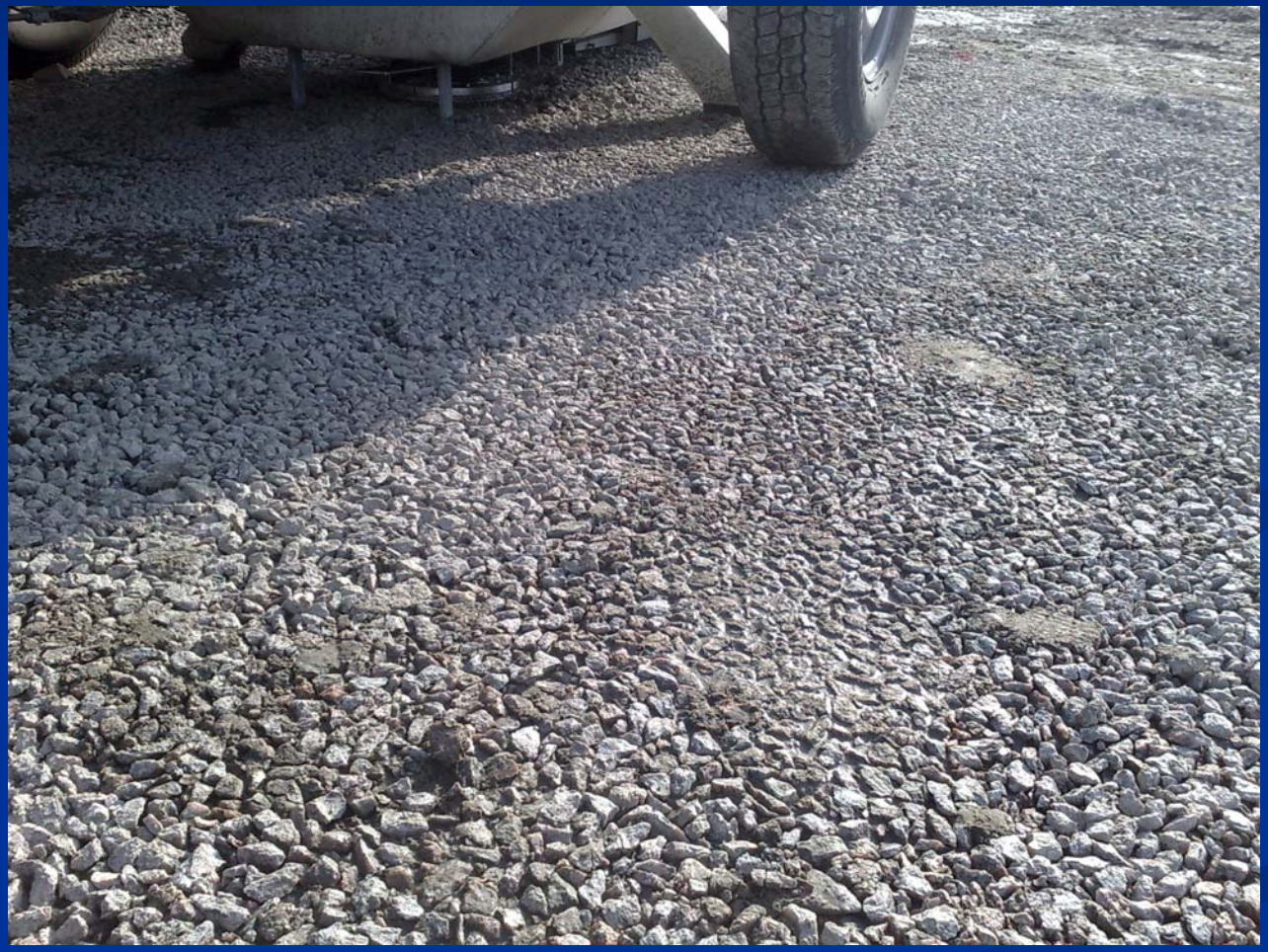
- 3 of 6 values failed Static Plate Load Test, should be > 60 Mpa
- What about standard FWD?
  - Advantage :
    - More sensors
    - Deeper penetration,
    - Many load levels et cetera

Construction Site
Southern side

Layout of test



Northern side surface



Embankment

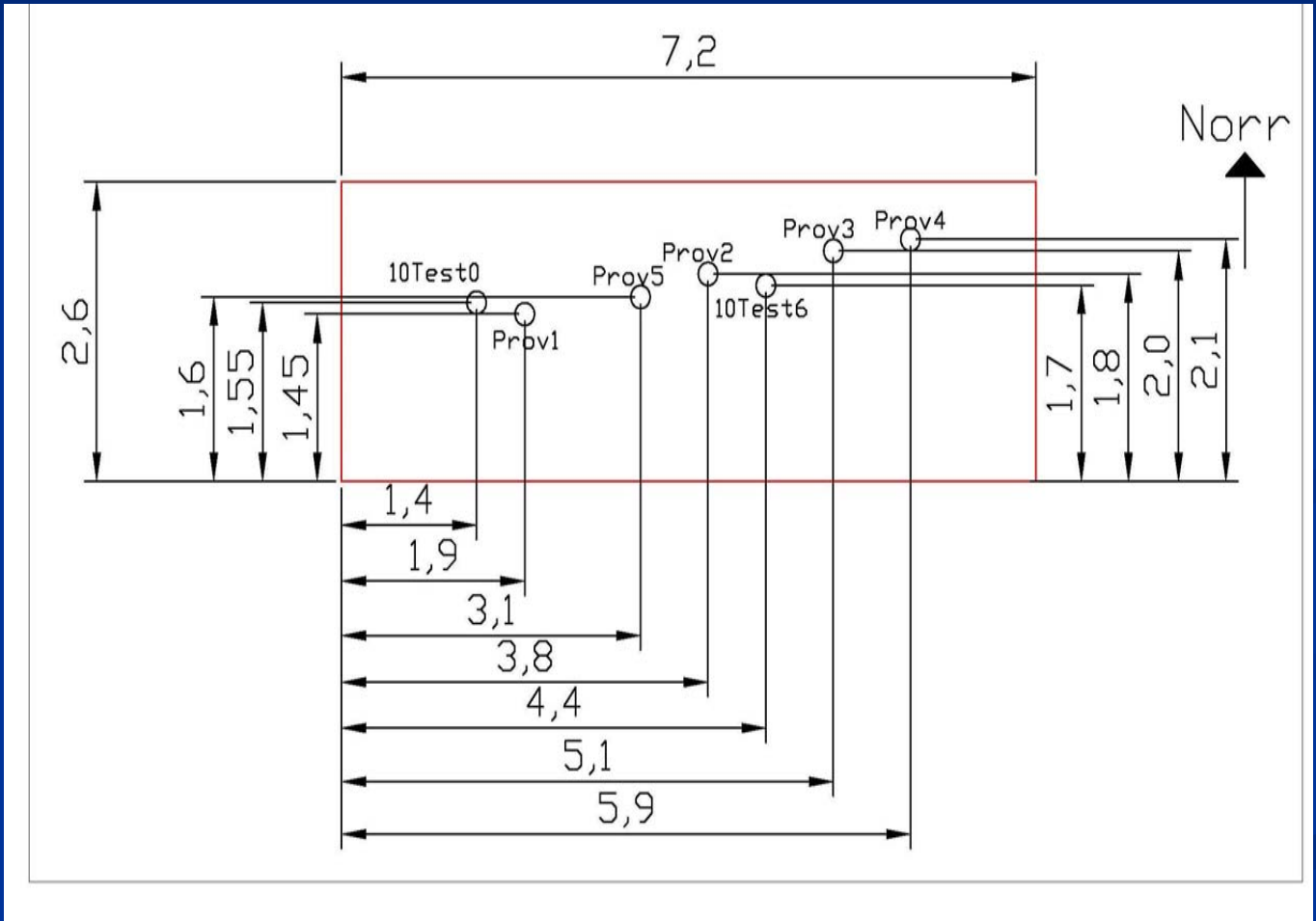
- 1.8 m resting on lime columns
- Geogrid used at three levels
- Many lifts with extra compaction efforts

Embankment

- FWD layers (model by choice)
  - 0-15 cm
  - 15-45 cm
  - 45- 120 cm
  - Subgrade

  These layers were chosen reflecting sensor spacing

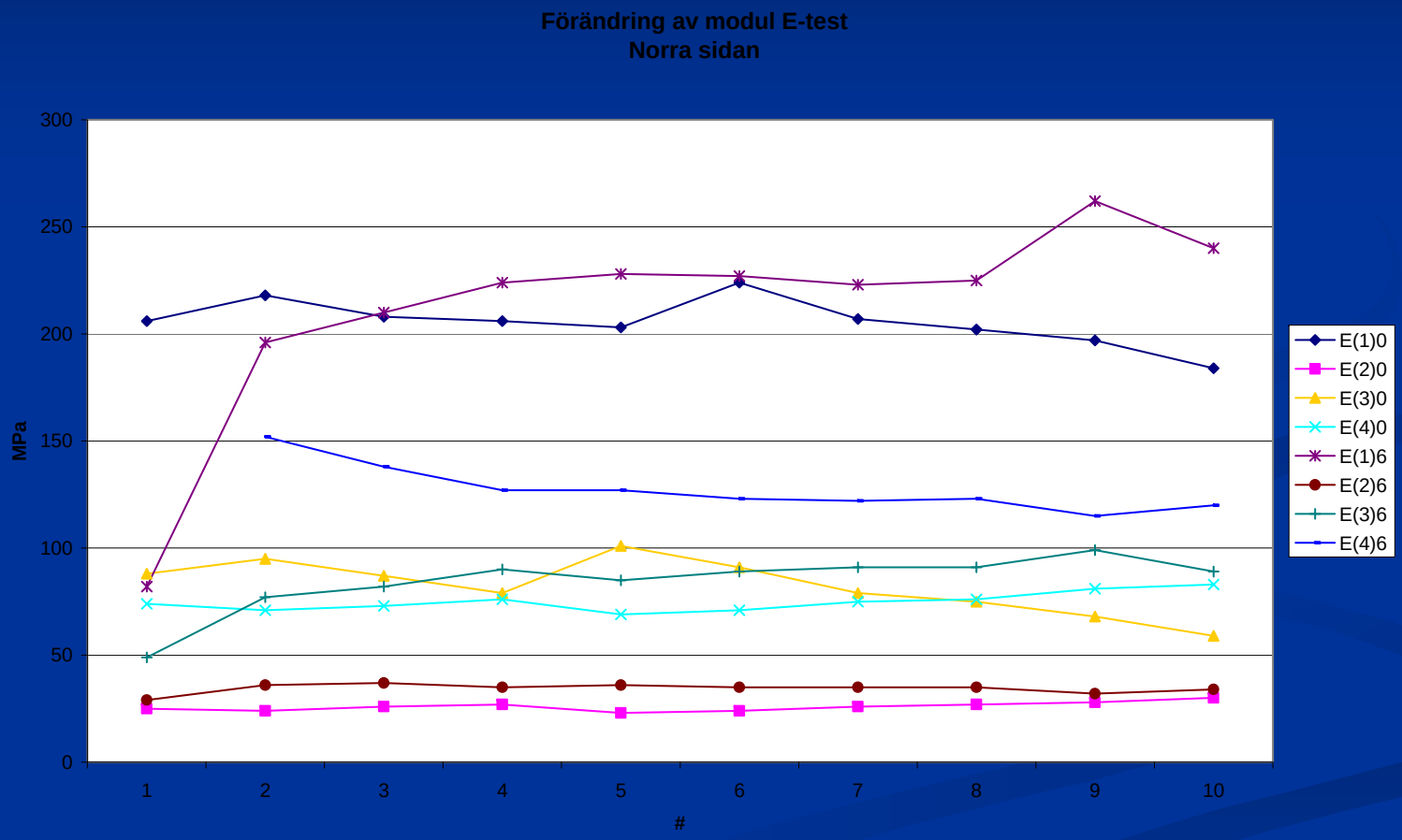
Northern side test layout



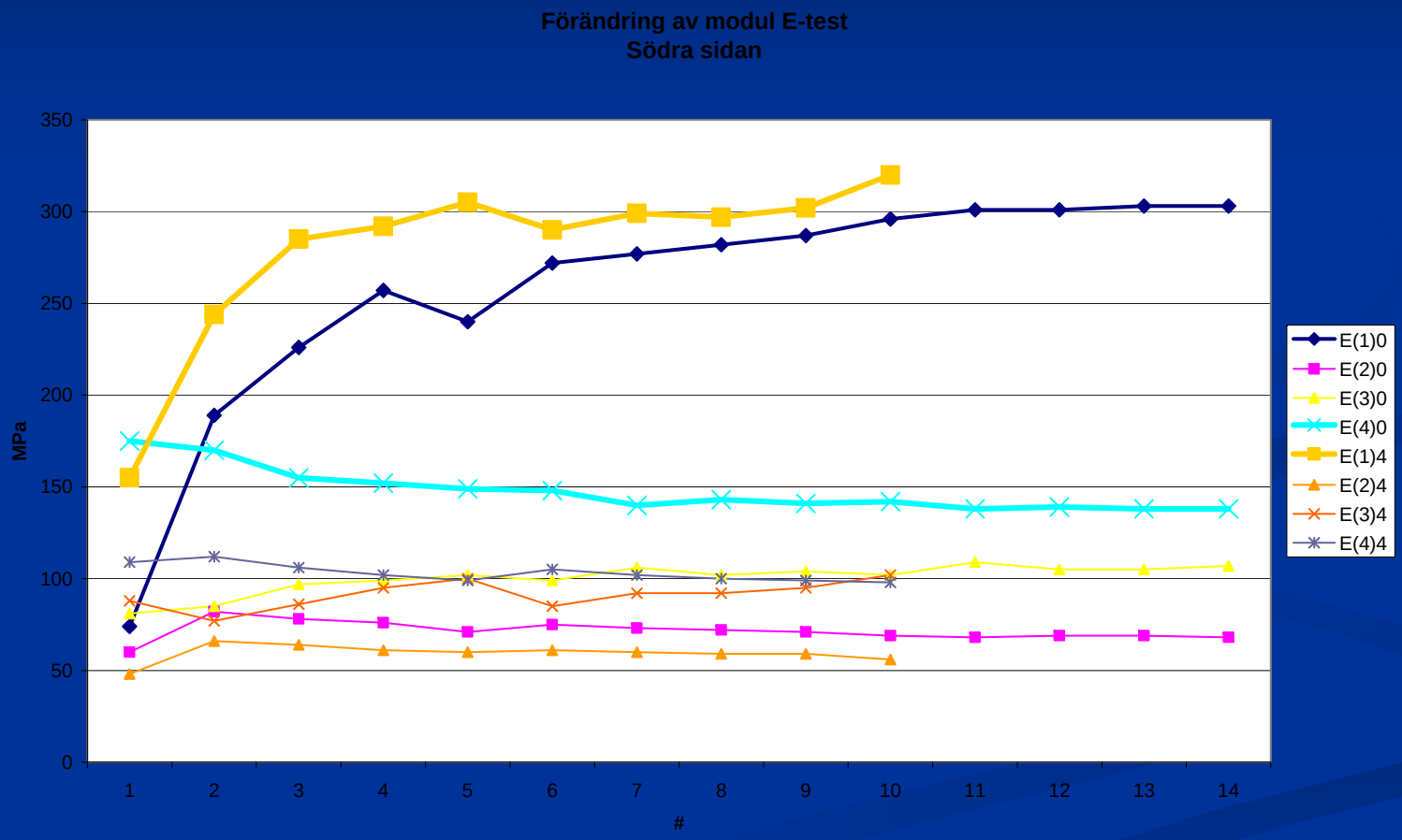
First objective
Compaction

- Repeated testing at same load level.
- Good compaction if deflections do not change with number of drops!
- Note, change is expected for first two or three drops. (Conditioning of test).

Change of modulus
Northern side, repeated tests



Change of modulus
Southern side, repeated tests



Second objective
E-moduli and stress sensitivity

- Repeated testing at different load levels.
- Good compaction if stress sensitivity does not change with number of sequences!
- Progressive loads to see if sudden drops in modulus indicate shear failures.

Drop sequences. Load in kilonewton

Table 2. Drop sequences. Load in kilonewton. S = South side, N = North side.

	Station	10-0	0	1	2	3	10-4	10-0	1	2	3	4	5	10-6
Drop	Side	S	S	S	S	S	S	N	N	N	N	N	N	N
1		50	20	20	20	20	50	50	20	20	20	20	20	50
2		50	20	20	20	20	50	50	20	20	20	20	20	50
3		50	40	40	40	40	50	50	40	40	40	40	40	50
4		50	50	50	50	50	50	50	40	40	40	40	40	50
5		50	20	20	20	20	50	50	50	50	50	50	50	50
6		50	20	20	20	20	50	50	20	20	20	20	20	50
7		50	40	40	40	40	50	50	20	20	20	20	20	50
8		50	50	50	50	50	50	50	40	40	40	40	40	50
9		50	20	20	20	20	50	50	40	40	40	40	40	50
10		50	20	20	20	20	50	50	50	50	50	50	50	50
11		50	40	40	40	40			20	20	20	20	20	
12		50	50	50	50	50			20	20	20	20	20	
13		50							40	40	40	40	40	
14		50							40	40	40	40	40	
15									50	50	50	50	50	

Results, moduli at different depths

Table 3. Moduli MPa North Side @50 kN

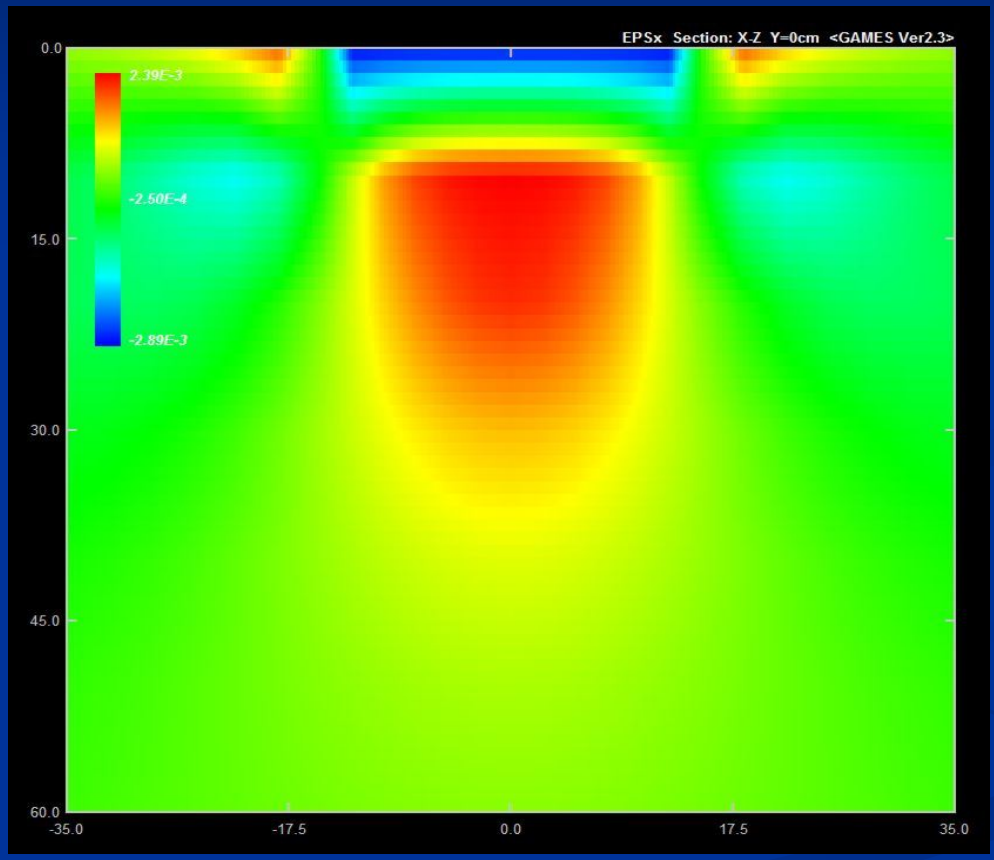
Station	Surface Modulus (last drop)	0-15 cm	15-60 cm	60-180 cm	Subgrade
1	61	157	32	49	88
2	83	254	35	117	92
3	108	303	50	90	135
4	108	280	58	109	105
5	83	360	24	774	41

Table 4. Moduli MPa South Side @ 50 kN

Station	Surface Modulus (last drop)	0-15 cm	15-60 cm	60-180 cm	Subgrade
0	99	261	52	105	116
1	129	328	79	111	137
2	100	270	52	128	99
3	109	313	65	62	119

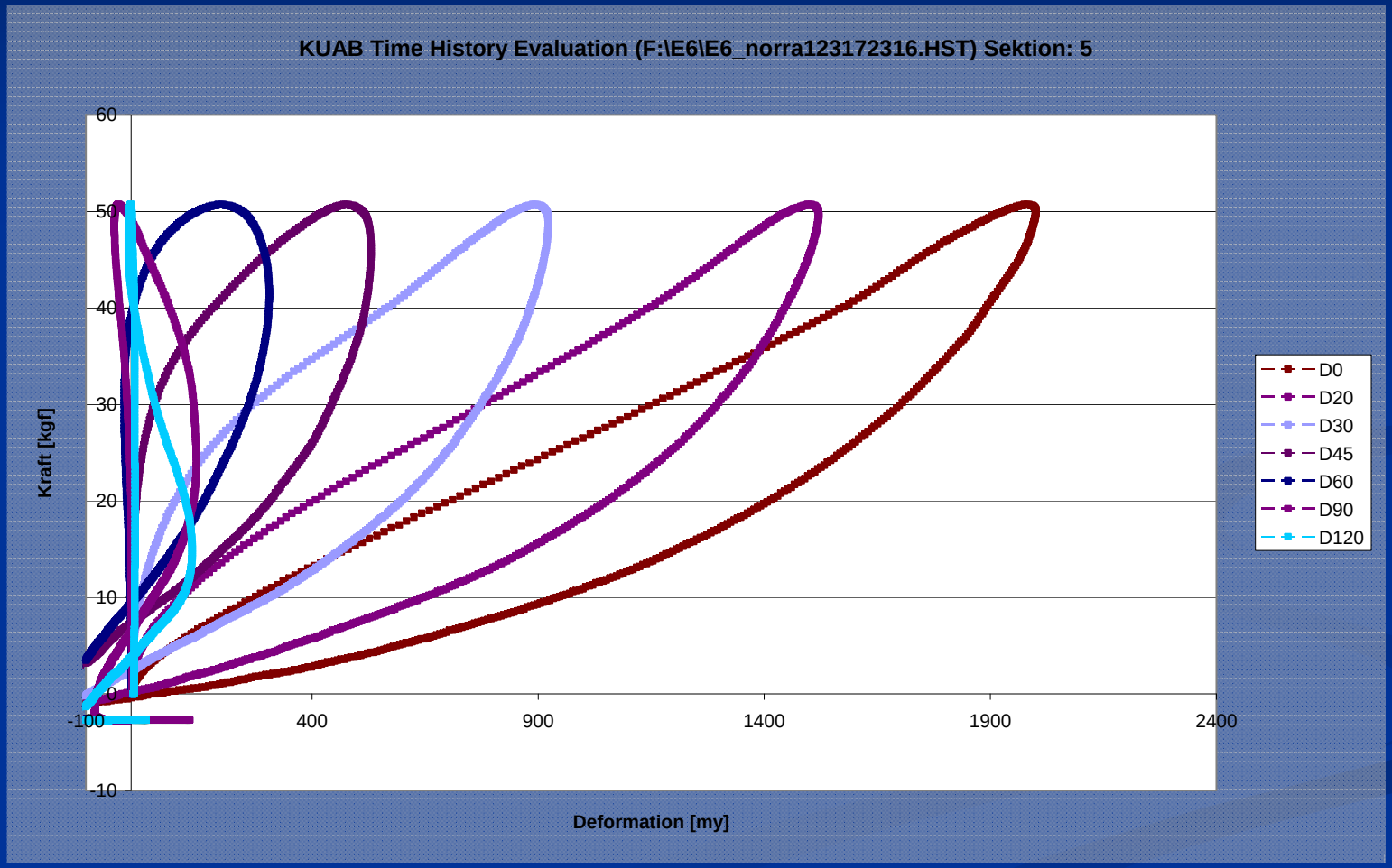
15-60 cm (½ - 2') always lower. Why?

Horizontal strain in a homogenous layer- Blue color shows compression zones. Red color shows tension.



With a large load the maximum tensile strain occurs at 15 cm depth !

Load-displacement diagram



Note behavior of D90 and D120!

Coefficients, k_2

$$E = k1*(\sigma 1 + \sigma 2 + \sigma 3)^{k2}$$

Table 5. Coefficient k_2 Northern side last drop sequence

Station	0-15 cm	15-60 cm	60-180 cm	Subgrade
1	.342	.296	.784	5.040
2	.307	.249	.777	4.878
3	.185	.230	.528	6.581
4	.225	.265	.610	4.999
5	.251	.206	1.639	9.409

Table 6. Coefficient k_2 Southern side last drop sequence

Station	0-15 cm	15-60 cm	60-140 cm	Subgrade
0	.196	.251	.437	3.759
1	.235	.276	.171	5.252
2	.245	.292	.176	5.236
3	.146	.329	.375	5.602

K2 is usually around .35 in tri-axial tests

Conclusions about site

- A relatively large deformation took place at or near ground water table level.
- Compaction was satisfactory
- Geotechnical expertise satisfied with result and construction could continue.

Conclusions about FWD

- FWD could access and test on gravel surfaces
- FWD could discern where (at what depth) deformation occurred. SLP could not
- Much more information, like stress sensitivity and moving water could be determined with an FWD