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POROČILO
O MERITVAH NOSILNOSTI PILOTOV

Objekt: **ŠPORTNA DVORANA VRHNIKA**

Lokacija: **VRHNIKA**

Naročnik: **SGP GRADITELJ d.d.**
Maistrova 7, SI-1241 KAMNIK

Investitor: **OBČINA VRHNIKA**
Tržaška cesta 1, SI-1360 VRHNIKA

Št. por.: PDA05-01-2025 ŠPORTNA DVORANA-VRHNIKA
Datum: APRIL 2025

Meritve izvedla:
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Pregledal:
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IVAN LESJAK
u niv. dipl. inž. grad.
IZS G-1625

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PRILOGE

1 SITUACIJA PILOTOV
2 REZULTATI MERITEV IN ANALIZ
3 DINAMIČNI OBREMENILNI TEST - OPIS POSTOPKA
4 FOTOGRAFIJE
5 CERTIFIKAT O USPOSOBLJENOSTI
6 OPREMA IN KALIBRACIJSKI LISTI



1. UVOD

Objekt: ŠPORTNA DVORANA - VRHNIKA
Lokacija: VRHNIKA
Projektant: DM-Metal d.o.o., Šentjanž pri Dravogradu
Izvajalec pilotov: SLEMENŠEK d.o.o., Ravne na Koroškem
Geotehnični nadzor: SLP d.o.o. LJUBLJANA, Ljubljana

Meritve: Kontrola nosilnosti z dinamično metodo
Izvajalec meritev: SLP d.o.o. LJUBLJANA, Ljubljana
Datum: 09.04.2025 (4x meritev)
SKUPAJ MERJENO: 4 piloti

Na štirih (4) uvrtanih AB pilotih so se izvedli testi nosilnosti z uporabo dinamične metode za preverjanje računske vertikalne statične nosilnosti pilotov. Piloti so izvedeni v konstrukciji bodočega objekta.

2. PODATKI O PILOTIH IN SESTAVI TEMELJNIH TAL

Za temeljenje predvidenega novega objekta športne dvorane na Vrhniki so se pred pričetkom pilotiranja izvedli štirje testni uvrtani AB piloti, premera 80 cm, dolžine 25 m.

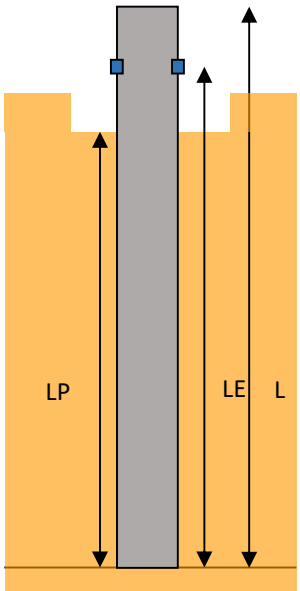
Beton pilotov: C30/37; XC3 XF1 XD2 XA1 S4; Dmax=16mm;
Armatura: S500; 12ϕ28mm, stremena ϕ12mm/15cm

Piloti so izvedeni skozi umetni nasip, slabo nosilne glinaste zemljine, sivo glono z organskimi primesmi v prodnato peščeno plast. Iz posredovanih Poročil o izdelavi pilotov s strani izvajalca pilotiranja je v spodnji preglednici razvidna tipična sestava temeljnih tal. Vsi štirje testni piloti premera fi80cm so izvedeni 2 m peščeno prodnato plast. V dnu izkopov so se izvedli SPT testi (rezultati so v RL-Rojstnih listih pilotov).

Sestava tal v spodnji preglednici 1 je povzeta po Poročilu o izdelavi pilota P25 z dne 27.2.2025, od kote delovnega platoja cca +293,08 m NMV.

PREGLEDNICA 1: Osnovni geotehnični podatki o tleh

Globina [m]	Sestava tal
0 – 0,5	Umetni nasip (NASIP)
0,5 – 2,0	Rjava zameljena glina z vložki grušča
2,0-17,0	Siva mastna glina
17,0-19,5	Siva glina z organskimi primesmi, rjave do črne barve
19,5-21,5	Peščeno prodnata plast granulacije do 16mm



Slika 1: Skica testnega pilota in sestava tal

Po izvedbi pilotov je bila glava vsakega pilota očiščena do zdravega betona in izveden betonski podaljšek dolžine cca 2 m za izvedbo dinamičnih testov. Beton podaljška smo pred izvedbo testa kontrolirali s sklerometrom, ki je pokazal vrednost tlačne trdnosti betona v času testa =>30 MPa.

PREGLEDNICA 2: Osnovni tehnični podatki o pilotih

Test	Pilot	Tip pilota	Izvajalec	Zabijalo		Datum Testa	ED/RD	L	LE	LP
No.	Oznaka		ime podjetja		kNm			m	m	m
1	25	UVRT80	Slemenšek	PP-12t	120	09/04/2025	RD43	27,0	25,4	25,0
2	20	UVRT80	Slemenšek	PP-12t	120	09/04/2025	RD28	27,0	17,0	16,0
3	55	UVRT80	Slemenšek	PP-12t	120	09/04/2025	RD34	27,0	25,4	24,9
4	51	UVRT80	Slemenšek	PP-12t	120	09/04/2025	RD32	27,0	25,4	24,9

LEGENDA:

ED/RD - konec zabijanja/ ponovno zabijanje

L - Skupna dolžina pilota

LE - Dolžina pilota pod senzorji

LP - Dolžina pilota v tleh ob koncu meritev

Pred pričetkom testov in po koncu testa so bili vsi testni piloti testirani na zveznost s PIT metodo.

3. OPREMA ZA ZABIJANJE IN TESTIRANJE PILOTOV

Za testiranje se je uporabilo prosto padno zabijalo SLP PP-12 ton.

PREGLEDNICA 3: Osnovni tehnični podatki o zabijanju

Tip zabijala z oznako:	**SLP PP-12 ton**
Teža udarnega bata:	120 kN
Maksimalna teoretična energija pri zabijanju Er:	Za 1 m padca bata uteži: 12 kNm (kJ)
Dušilni material zabijala:	Vezana plošča 3 cm
Dušilni material pilota:	Pesek SU 1cm + vezana plošča 2x 3 cm
Maksimalna višina padca :	H <= 2.0 m / 2.0 m

Med glavo pilota in kapo zabijala smo, poleg izravnalnega drobnega peska, položili 6 cm debelo leseno vezano ploščo. Na udarni plošči zabijala smo kot dušilni material uporabili 3 cm debelo vezano ploščo.

4. METODA MERITEV IN ANALIZE

Na kol, ki ga zabijamo (po glavi udarjamo), pritrdimo senzorje za merjenje deformacij in pospeškov. Senzorji so pritrjeni osno simetrično na vsaki strani, cca. 2 premera pod glavo kola. Z zabijalom povzročeni tlačni napetostni val potuje po kolu navzdol, ter se po odboju na konici vrača nazaj. S senzorji zaznani napetostni valovi se preko PDA-ja (Pile Driving Analyser) obdelajo, tako da dobimo ob vsakem udarcu zabijala na zaslonu takojšen prikaz poteka sile in hitrosti pomika merskega mesta v odvisnosti od časa. Vsi podatki se snemajo na trdi disk, da jih po zabijanju ponovno podrobno analiziramo.

Metoda in postopek meritev je standardizirana s standardom ASTM D-4945-17 "Standard test Method for High-Strain Dynamic Testing of Deep Foundation" in definirana s priporočilom nemškega združenja geomehanikov (Recommentatin for dynamic pile tests of Technical Committee 5 of the German Geotechnical Society).

Po izvedbi dinamičnega obremenilnega testa se posneti podatki sile in pospeška uporabijo za računalniško analizo s CAPWAP (CAse Pile Wave Analysis Program) programom, katerega osnova je valovna enačba. Modeliran kol in zemljino injiciramo z eno izmed merjenih krivulj, ter z iteracijami (spreminjanjem modela kola in zemljine) iščemo najboljši približek dejanski oz. drugi merjeni krivulji. Z zadovoljivim približkom merjeni krivulji so poznane lastnosti modela zemljine in mejna nosilnost testiranega kola. S postopnim obremenjevanjem tako določenega modela kola in zemljine (računalniška simulacija statičnega obremenilnega testa) dobimo graf obtežba-pomik testiranega kola.

5. POTEK TESTIRANJA

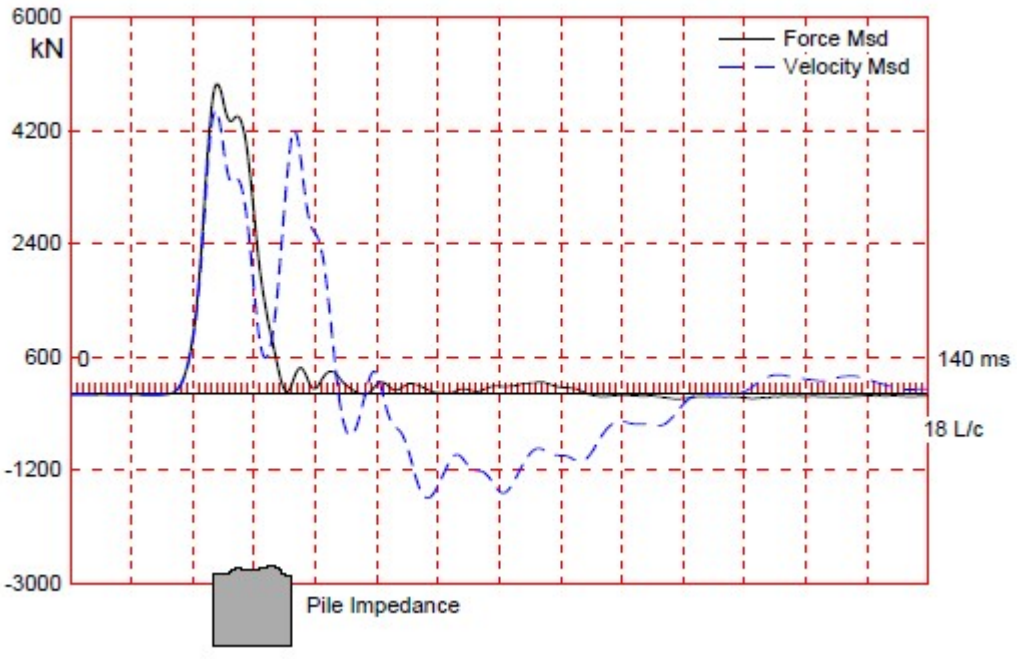
Na vse pilote so bili pritrjeni po štirje pari senzorjev osno simetrično.

Ob izvedbi testiranja smo prilagodili višino padca uteži odporom tal in notranjim silam v pilotu med izvajanjem testa.

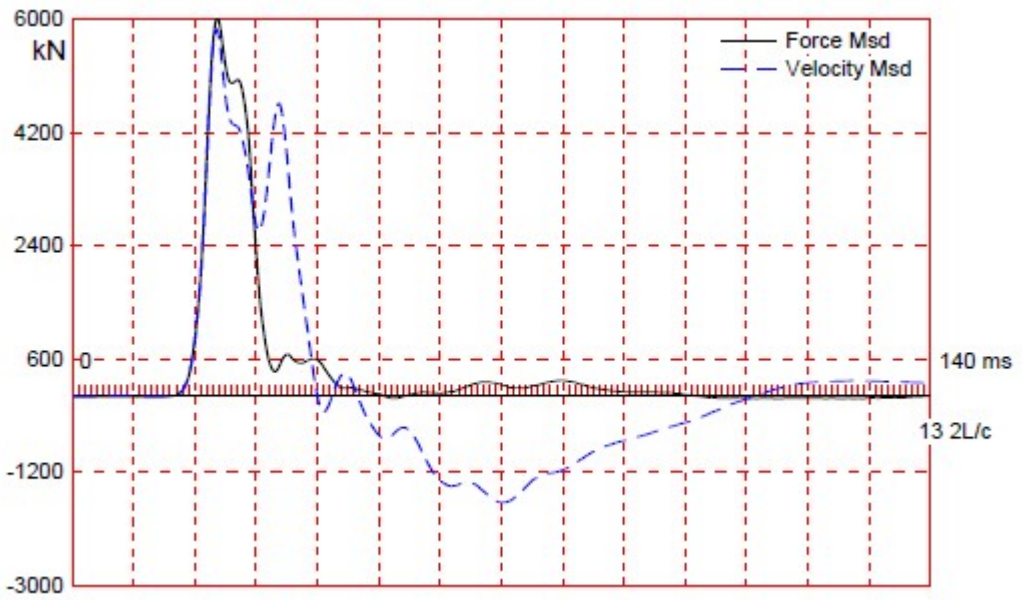
PREGLEDNICA 4: Izvajanje dinamičnih testov in meritev

Test	Pilot	Tip pilota	ED/RD	L	LE	LP	1 H/set		2 H/set		3 H/set		4 H/set		5 H/set		6 H/set		7 H/set		set
No.	Oznaka			m	m	m	m	mm	m	mm	m	mm	m	mm	m	mm	m	mm	m	mm	Σmm
1	25	UVRT80	RD43	27,0	25,4	25,0	0,40	5,0	0,40	3,0	0,40	3,0	0,70	5,5	0,70	4,5	0,70	3,5	0,90	5,0	30
2	20	UVRT80	RD28	27,0	17,0	16,0	0,20	2,0	0,40	5,0	0,50	4,0	0,70	5,0	0,70	4,0	0,90	8,0			28
3	55	UVRT80	RD34	27,0	25,4	24,9	0,20	2,0	0,40	5,0	0,40	3,0	0,70	5,0	0,70	4,0	0,90	8,0			27
4	51	UVRT80	RD32	27,0	25,4	24,9	0,16	0,0	0,40	3,0	0,40	3,0	0,70	5,5	0,70	4,5	0,90	6,5			23

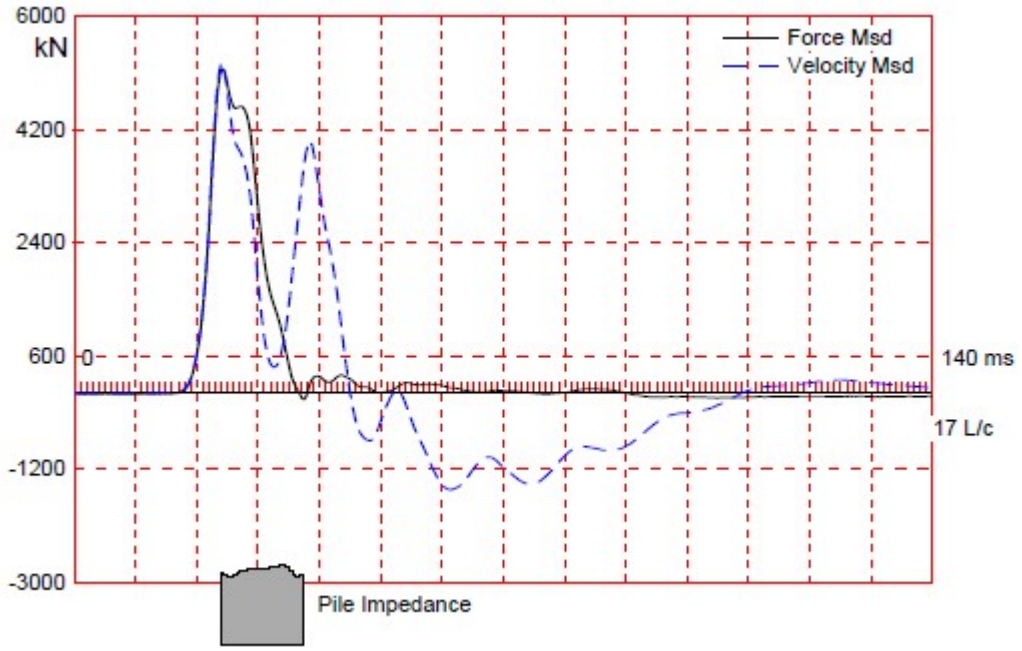
LEGENDA:
ED/RD - konec zabijanja/ ponovno zabijanje
L - Skupna dolžina pilota
LE - Dolžina pilota pod senzorji
LP - Dolžina pilota v tleh ob koncu meritev
H/E - višina padca zabijala v m ali drugače definirana nastavitev zabijala
set - Pomik/Ugrez pilota za izbran udarec



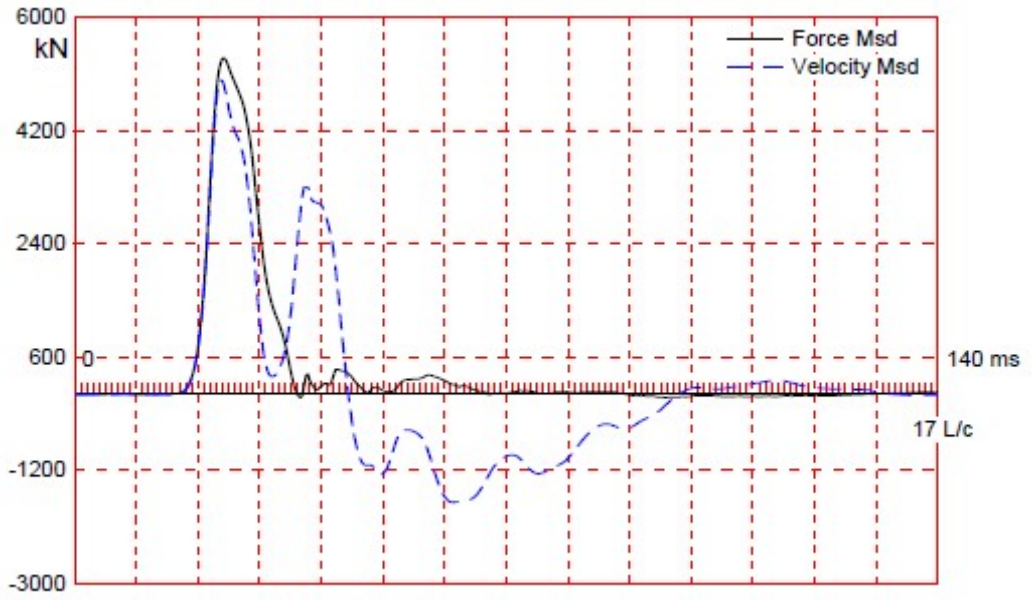
Slika 2: Merjena sila in hitrost pomika na glavi testnega pilota 25 (RD43)



Slika 3: Merjena sila in hitrost pomika na glavi testnega pilota 20 (RD28) - krajši



Slika 4: Merjena sila in hitrost pomika na glavi testnega pilota 55 (RD34)



Slika 5: Merjena sila in hitrost pomika na glavi testnega pilota 51 (RD32)

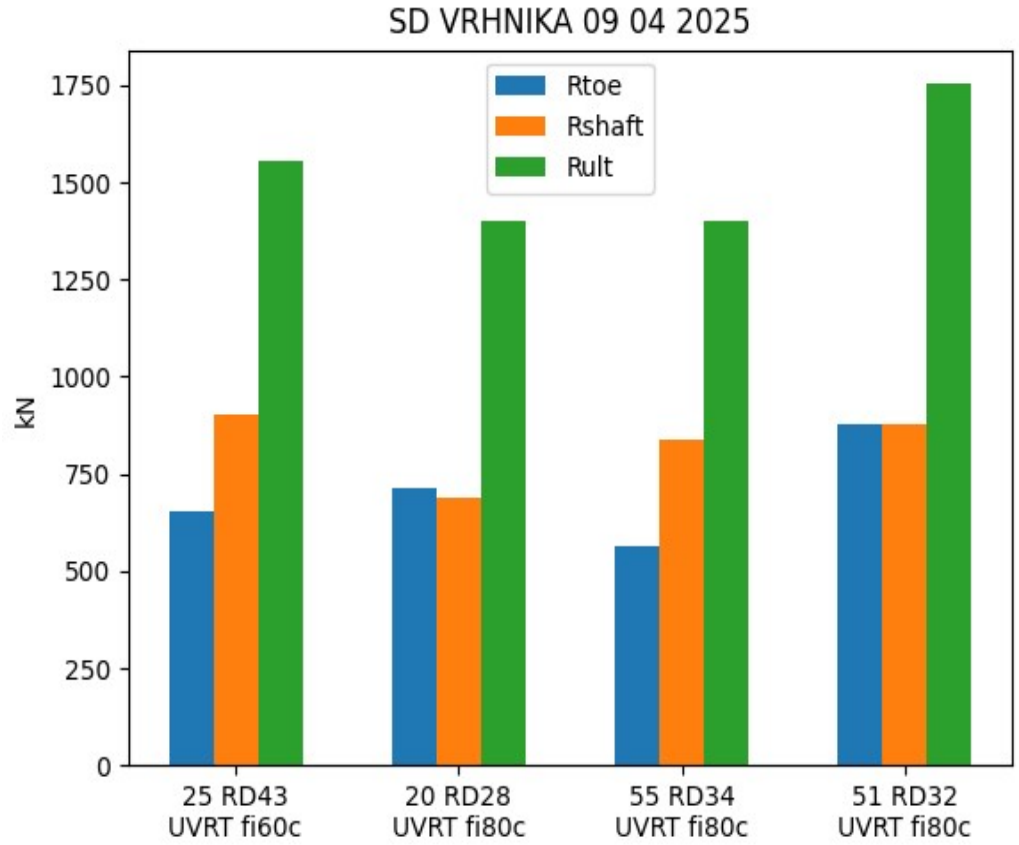
6. REZULTATI DINAMIČNIH OBREMENILNIH TESTOV

Po analizi podatkov terenskih meritev je bil karakterističen udarec analiziran s programom CAPWAP (signal matching) ter definirana sledeča nosilnost pilotov:

PREGLEDNICA 5: Rezultati CAPWAP analize

					CAPWAP							
Test	Pilot	Tip pilota	ED/RD	L	Blow	set/ ud	EMX	CSX	Rskin	Rtoe		Ruk_CW
No.	Oznaka			m	no.	mm	kNm	MPa	kN	kN		kN
1	25	UVRT80	RD43	27,0	3	5,5	31,0	9,8	903	654	=	1.557
2	20	UVRT80	RD28	27,0	5	4,0	45,5	12,1	689	711	=	1.400
3	55	UVRT80	RD34	27,0	3	5,0	34,1	10,6	838	563	=	1.401
4	51	UVRT80	RD32	27,0	4	5,5	34,9	10,7	876	877	=	1.753

LEGENDA:
ED/RD - konec zabijanja/ ponovno zabijanje
L - Skupna dolžina pilota
LE - Dolžina pilota pod senzorji
LP – Dolžina pilota v tleh ob koncu meritev
Blow – Izbrani udarec
set - Pomik/Ugrez pilota za izbran udarec
EMX - Maksimalna prenesena energija
CSX - Maksimalna tlačna napetost pri testu
Rskin- Statična nosilnost plašča pilota določena z CW (signal matching)
Rtoe - Statična nosilnost konice pilota določena s CW (signal matching)
Ru - Statična nosilnost pilota določena s CW; Mejna nosilnost-aktiviran odpor tal



7. UGOTOVITVE

Na osnovi meritev in CAPWAP analize lahko ugotovimo sledečo nosilnost testnih pilotov:

PREGLEDNICA 6: Mejne nosilnosti testiranih pilotov

"ŠPORTNA DVORANA - VRHNIKA", Vrhnika

Test	Pilot	Tip pilota	ED/RD	LP	Ruk_CW
No.	Oznaka pilota	Tip	Dni	m	kN
1	**25**	UVRT80	RD43	25,0	= **1.557**
2	**20**	UVRT80	RD28	16,0	= **1.400**
3	**55**	UVRT80	RD34	24,9	= **1.401**
4	**51**	UVRT80	RD32	24,9	= **1.753**

OPOMBA

LP - Dolžina pilota v tleh ob koncu meritev

Ruk-CW - Statična nosilnost pilota določena s CW; Mejna nosilnost-aktiviran odpor tal;

- Ugotovljena nosilnost velja za čas testiranja in geotehnične pogoje v času testiranja (dolžina pilota v zemljini, nivo talne vode, itd.).
- Mejna nosilnost tal (odpor tal) je bila v celoti aktivirana pri vseh testiranih pilotih.

- Pilot 20 je močno poškodovan oz ima zelo zmanjšan presek ali kvaliteto betona na več lokacijah globje od 16 m. Popolnoma zanesljive analize nosilnosti pilota 20 ni bilo mogoče narediti. Vsekakor pa pilot ni popolnoma prekinjen. Glede na analize je pričakovati podobno nosilnost po zemljini kot pri ostalih pilotih. CW analiza je bila zato na tem pilotu narejena kot da je dolžina pilota v tleh LP=16m.

- Na pilotih ni odzivov, razen na pilotu 20, ki bi kazali na poškodbe. Ostali trije piloti so zvezni.

Projektni odpor $R_{c,d}$ (MSN) glede na število izvedenih PDA-DLT meritev skladno z EC7 je podan za pilot fi80cm. Pri tem so upoštevani rezultati CW analiz za tri pilote 25, 55 in 51.

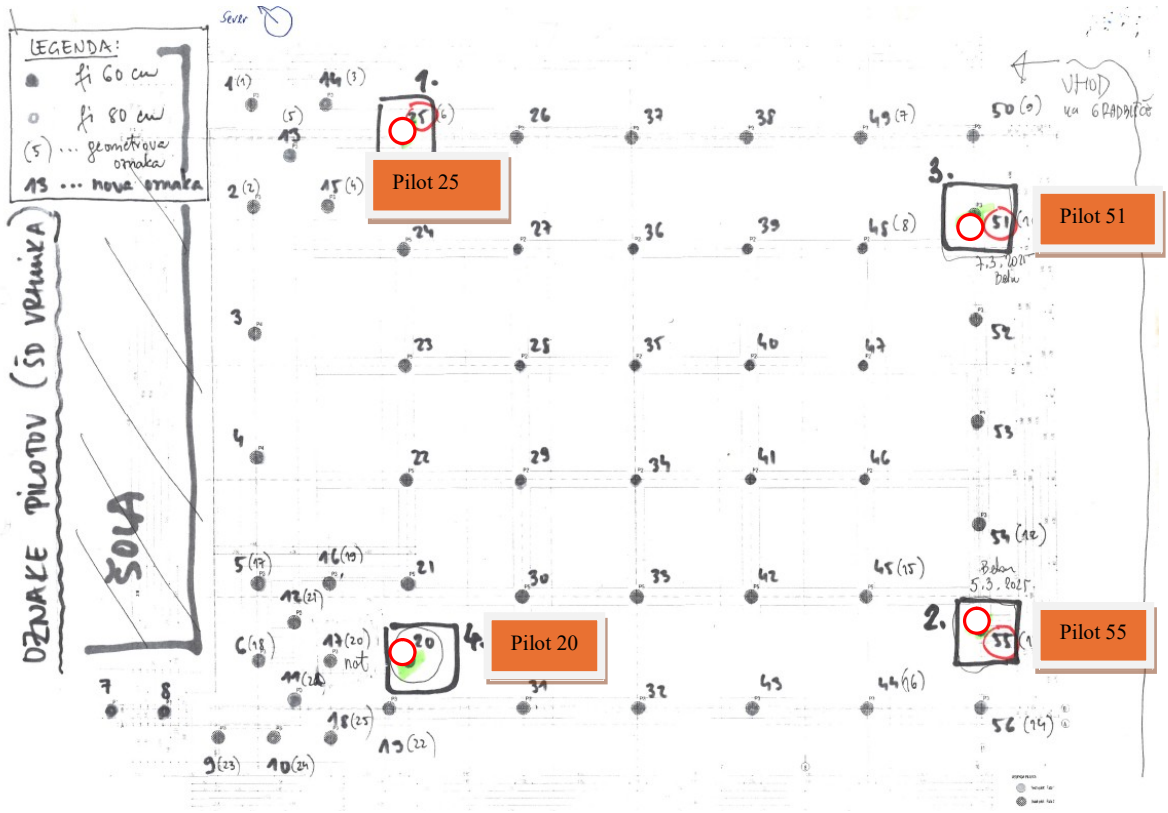
Pilot fi80cm, LP=25,0m; Rc,d (MSN)= 999 kN.

	R2 >	γ =	1,1
	kN	$\xi 5/6$	kN
avg	1570	1,36	1.155
min	1401	1,28	1.099
no	3	**Rcd =**	**999**

Obdelal:

Gorazd STRNIŠA, univ.dipl.inž.grad.

PRILOGA
1 SITUACIJA PILOTOV



PRILOGA
2 REZULTATI MERITEV IN ANALIZ

V prilogah so za vsak testiran kol podani sledeči podatki :

2./ Na **prvem listu** so rezultati dinamične in statične analize:
- slika na levem zgornjem delu predstavlja *ujemanje računske in merjene krivulje sile* v odvisnosti od časa
- slika v desnem zgornjem delu predstavlja *merjeno silo in hitrost* za analizirani udarec v odvisnosti od časa
- slika predstavlja *simulacijo statične obremenilne preizkušnje* prikazane grafično v diagramu obtežba-posedek kola. Krivulja ne prikazuje popolnoma enakega obnašanja kola oz. zemljine kot bi bil ob izvedbi klasične obremenilne preizkušnje. Vzrok za to je ta, da v krivulji ni upoštevano lezenje. Zato bi krivulja iz statične obremenilne preizkušnje izvedene po ASTM standardu (ML postopek) bila bolj zaokrožena, v prvem delu višja in nižja v zadnjem delu.
- in slika v desnem spodnjem delu predstavlja grafično razporeditev odpornosti zemljine ob kolu in distribucijo odpora ob plašču in konici kola.

1./Na **drugem listu** so osnovni rezultati pridobljeni z CAPWAP analizo:
- elastične deformacije zemljine
- statične nosilnosti posameznih slojev zemljine
- dušenje zemljine ..... itd.

3./ Na **tretjem listu** so rezultati maksimalnih in minimalnih vrednosti za sile, napetosti, energijo, hitrosti in pomike kola pri analiziranem udarcu. Spodaj so rezultati CASE metode.

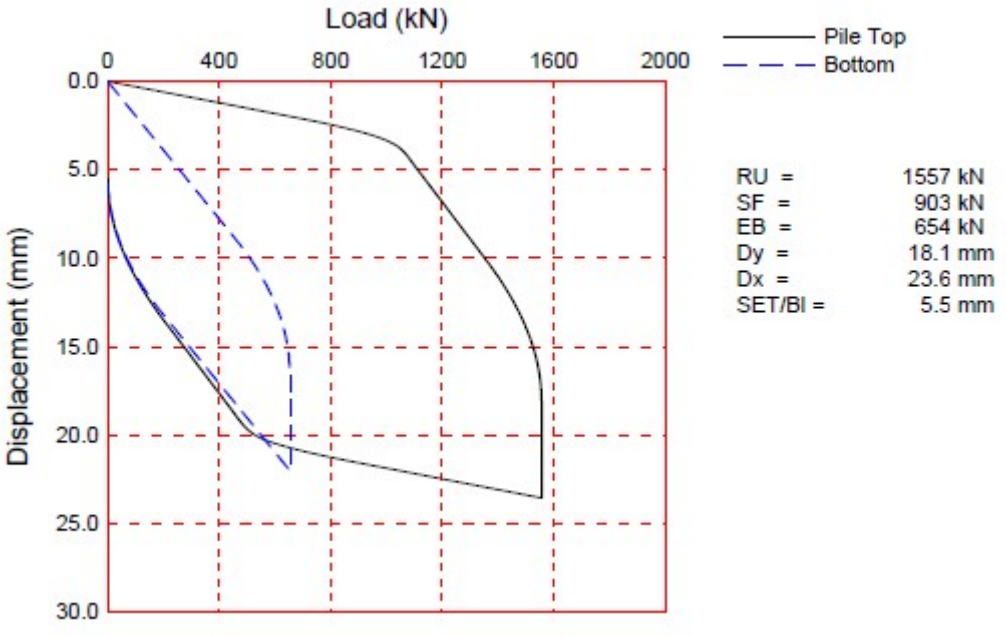
4./ Na **četrtem listu** so osnovni vhodni podatki o kolu

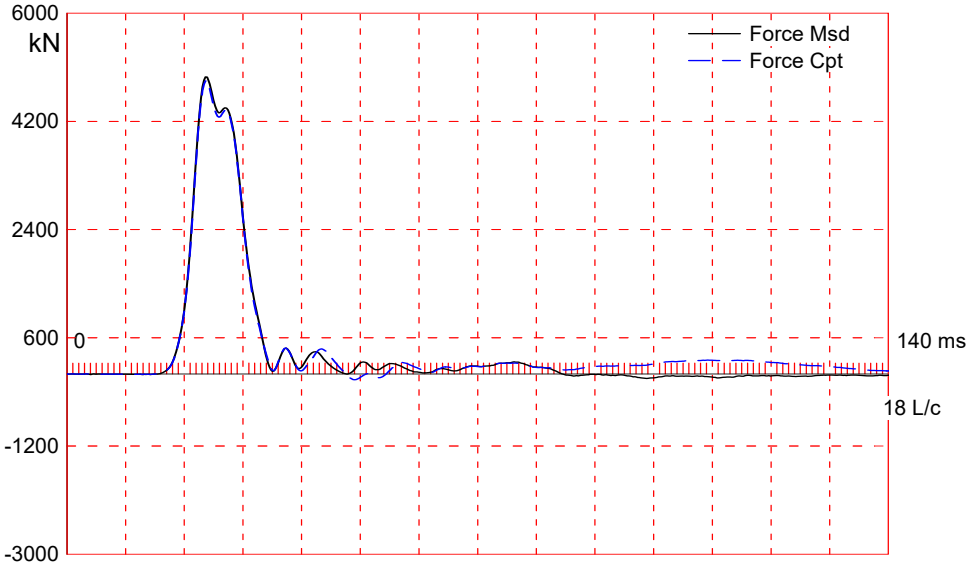
5./. Na **petem listu** so delni rezultati in vhodni podatki dinamične analize

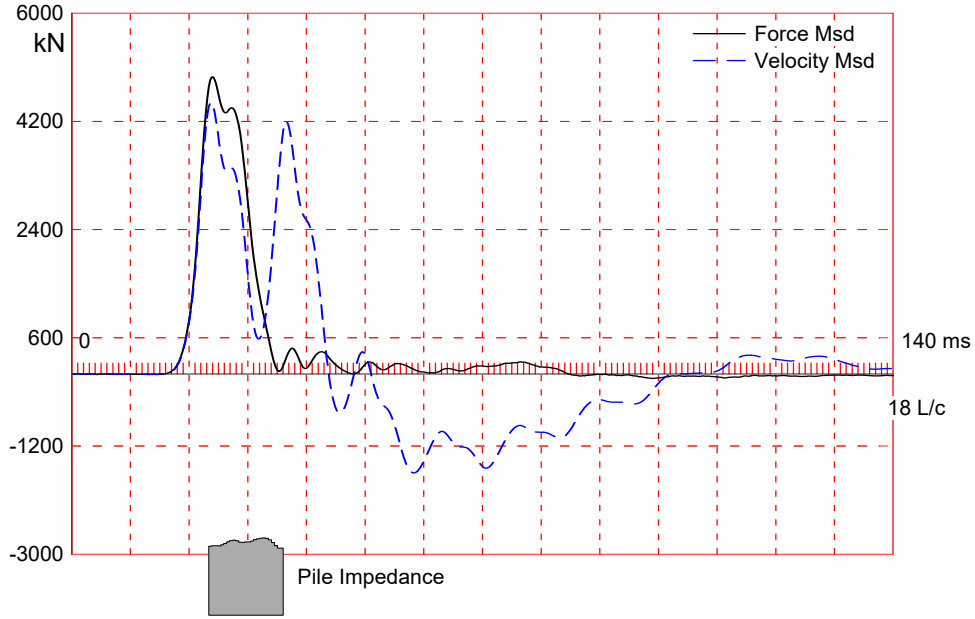
6./ V nadaljevanju so za obravnavan pilote tudi razpoložljivi podatki in rezultati terenskih zapisov posameznih udarcev (potek zabijanja kola), prikazani na grafu in tabelarično, zapisniki izvedbe, …

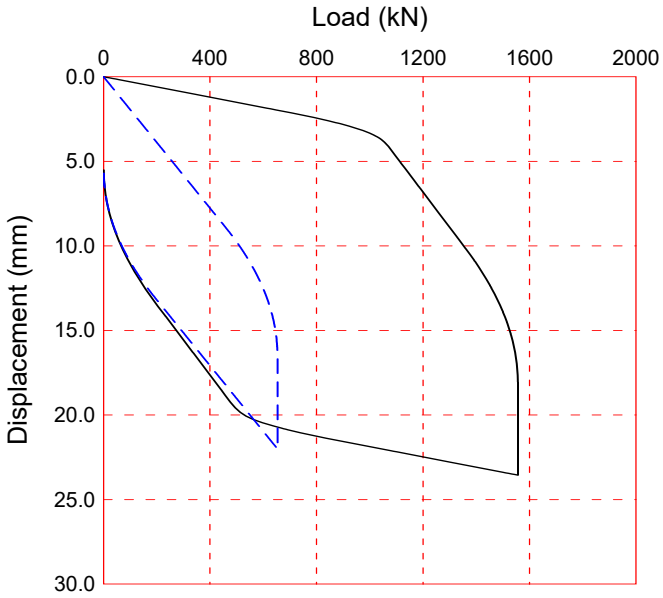
PDA-CAPWAP rezultati

1/ 25 UVRTϕ80 cm Ru = 1557 kN

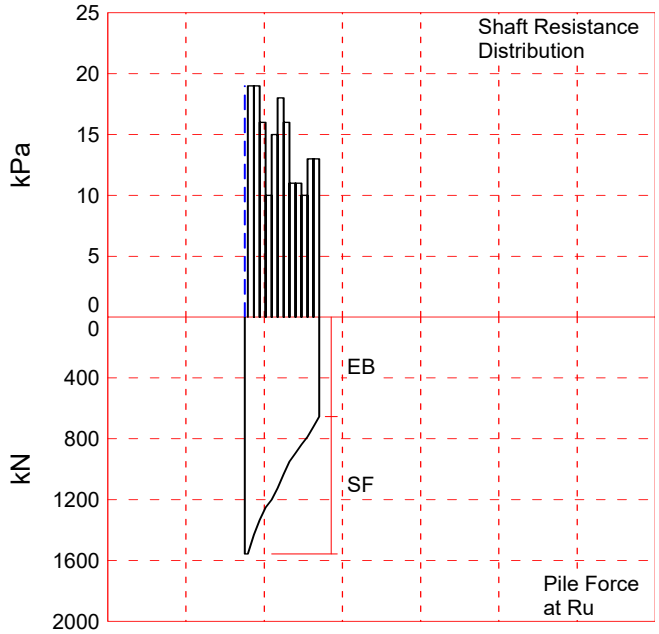








RU =	1557 kN
SF =	903 kN
EB =	654 kN
Dy =	18.1 mm
Dx =	23.6 mm
SET/Bl =	5.5 mm



Length b. Sensors	25.4 m
Embedment	25.0 m
Top Area	0.50 m^2
End Bearing Area	0.50 m^2
Top Perimeter	2.51 m
Top E-Modulus	34474 MPa
Top Spec. Weight	23.6 kN/m^3
Top Wave Spd.	3788 m/s
Overall W.S.	4000 m/s
Match Quality	1.98
Top Compr. Stress	9.8 MPa
Max Compr. Stress	10.1 MPa
Max Tension Stress	-3.03 MPa
Avg. Shaft Quake	2.6 mm
Toe Quake	12.7 mm
Avg. Shaft Smith Dpg.	1.40 s/m
Toe Smith Damping	1.00 s/m

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About the CAPWAP Results

The CAPWAP program performs a signal matching or reverse analysis based on measurements taken on a deep foundation under an impact load. The program is based on a one-dimensional mathematical model. Under certain conditions, the model only crudely approximates the often complex dynamic situations.

The CAPWAP analysis relies on the input of accurately measured dynamic data plus additional parameters describing pile and soil behavior. If the field measurements of force and velocity are incorrect or were taken under inappropriate conditions (e.g., at an inappropriate time or with too much or too little energy) or if the input pile model is incorrect, then the solution cannot represent the actual soil behavior.

Generally the CAPWAP analysis is used to estimate the axial compressive pile capacity and the soil resistance distribution. The long-term capacity is best evaluated with restrike tests since they incorporate soil strength changes (set-up gains or relaxation losses) that occur after installation. The calculated load settlement graph does not consider creep or long term consolidation settlements. When uplift is a controlling factor in the design, use of the CAPWAP results to assess uplift capacity should be made only after very careful analysis of only good measurement quality, and further used only with longer pile lengths and with nominally higher safety factors.

CAPWAP is also used to evaluate driving stresses along the length of the pile. However, it should be understood that the analysis is one dimensional and does not take into account bending effects or local contact stresses at the pile toe.

Furthermore, if the user of this software was not able to produce a solution with satisfactory signal "match quality" (MQ), then the associated CAPWAP results may be unreliable. There is no absolute scale for solution acceptability but solutions with MQ above 5 are generally considered less reliable than those with lower MQ values and every effort should be made to improve the analysis, for example, by getting help from other independent experts.

Considering the CAPWAP model limitations, the nature of the input parameters, the complexity of the analysis procedure, and the need for a responsible application of the results to actual construction projects, it is recommended that at least one static load test be performed on sites where little experience exists with dynamic behavior of the soil resistance or when the experience of the analyzing engineer with both program use and result application is limited.

Finally, the CAPWAP capacities are ultimate values. They MUST be reduced by means of an appropriate factor of safety to yield a design or working load. The selection of a factor of safety should consider the quality of the construction control, the variability of the site conditions, uncertainties in the loads, the importance of structure and other factors. The CAPWAP results should be reviewed by the Engineer of Record with consideration of applicable geotechnical conditions including, but not limited to, group effects, potential settlement from underlying compressible layers, soil resistances provided from any layers unsuitable for long term support, as well as effective stress changes due to soil surcharges, excavation or change in water table elevation.

The CAPWAP analysis software is one of many means by which the capacity of a deep foundation can be assessed. The engineer performing the analysis is responsible for proper software application and the analysis results. Pile Dynamics accepts no liability whatsoever of any kind for the analysis solution and/or the application of the analysis result.

CAPWAP SUMMARY RESULTS

Total CAPWAP Capacity: 1556.7; along Shaft 902.7; at Toe 654.0 kN

Soil Sgmnt No.	Dist. Below Gages m	Depth Below Grade m	Ru kN	Force in Pile kN	Sum of Ru kN	Unit Resist. (Depth) kN/m	Unit Resist. (Area) kPa
				1556.7			
1	3.0	2.6	126.4	1430.2	126.4	48	19
2	5.1	4.7	97.0	1333.2	223.5	48	19
3	7.1	6.7	81.7	1251.5	305.2	40	16
4	9.1	8.7	51.1	1200.4	356.3	25	10
5	11.2	10.8	76.6	1123.8	432.9	38	15
6	13.2	12.8	91.9	1031.9	524.8	45	18
7	15.2	14.8	81.7	950.2	606.5	40	16
8	17.3	16.9	56.2	894.0	662.7	28	11
9	19.3	18.9	56.2	837.8	718.9	28	11
10	21.3	20.9	51.1	786.7	769.9	25	10
11	23.4	23.0	66.4	720.3	836.3	33	13
12	25.4	25.0	66.4	654.0	902.7	33	13
Avg. Shaft			75.2			36	14
Toe			654.0				1301

Soil Model Parameters/Extensions		Shaft	Toe
Smith Damping Factor		1.40	1.00
Quake	(mm)	2.6	12.7
Case Damping Factor		0.28	0.14
Damping Type		Sm+Visc	Viscous
Unloading Quake	(% of loading quake)	265	123
Reloading Level	(% of Ru)	100	100
Unloading Level	(% of Ru)	0	
Resistance Gap (included in Toe Quake)	(mm)		2.4
Soil Support Dashpot		0.100	0.000
Soil Support Weight	(kN)	25.50	0.00

CAPWAP match quality = 1.98 (Wave Up Match) ; RSA = 0
Observed: Final Set = 5.5 mm; Blow Count = 182 b/m
Computed: Final Set = 6.7 mm; Blow Count = 149 b/m

Transducer F3 (X139) CAL: 91.3; RF: 1.00; F4 (T609) CAL: 141.3; RF: 1.00
F7 (370A) CAL: 93.2; RF: 1.00; F8 (371A) CAL: 94.0; RF: 1.00
A1 (K14321) CAL: 350; RF: 1.00; A2 (K14322) CAL: 359; RF: 1.00
A5 (K11170) CAL: 438; RF: 1.00; A6 (K11082) CAL: 441; RF: 1.00

max. Top Comp. Stress = 9.8 MPa (T= 24.4 ms, max= 1.027 x Top)
max. Comp. Stress = 10.1 MPa (Z= 3.0 m, T= 24.9 ms)
max. Tens. Stress = -3.03 MPa (Z= 8.1 m, T= 34.5 ms)
max. Energy (EMX) = 31.0 kJ; max. Measured Top Displ. (DMX)= 13.5 mm

EXTREMA TABLE

Pile Sgmnt No.	Dist. Below Gages m	max. Force kN	min. Force kN	max. Comp. Stress MPa	max. Tens. Stress MPa	max. Trnsfd. Energy kJ	max. Veloc. m/s	max. Displ. mm
1	1.0	4928.0	-220.1	9.8	-0.44	31.0	0.99	13.7
2	2.0	4994.0	-484.4	9.9	-0.96	30.9	0.98	13.6
4	4.1	4885.1	-1057.8	9.7	-2.10	28.6	0.95	13.5
6	6.1	4789.1	-1390.5	9.5	-2.77	26.8	0.94	13.4
8	8.1	4701.1	-1523.4	9.4	-3.03	25.6	0.92	13.4
9	9.1	4736.4	-1451.0	9.4	-2.89	25.3	0.92	13.4
10	10.2	4678.5	-1411.9	9.3	-2.81	24.3	0.91	13.5
11	11.2	4711.7	-1246.6	9.4	-2.48	24.0	0.94	13.5
12	12.2	4599.2	-1180.4	9.1	-2.35	22.5	1.02	13.6
13	13.2	4602.2	-1044.1	9.2	-2.08	22.5	1.10	13.6
14	14.2	4435.2	-1165.8	8.8	-2.32	20.7	1.16	13.6
15	15.2	4380.5	-1148.5	8.7	-2.28	20.7	1.20	13.6
16	16.3	4147.1	-1199.1	8.3	-2.39	18.9	1.23	13.6
17	17.3	4011.7	-1096.9	8.0	-2.18	18.9	1.24	13.6
18	18.3	3745.7	-1025.8	7.5	-2.04	17.6	1.24	13.6
19	19.3	3511.8	-827.9	7.0	-1.65	17.6	1.23	13.6
20	20.3	3148.3	-662.9	6.3	-1.32	16.2	1.26	13.6
21	21.3	2805.6	-379.3	5.6	-0.75	16.2	1.31	13.6
22	22.4	2344.8	-128.6	4.7	-0.26	15.0	1.36	13.6
23	23.4	1911.1	-3.7	3.8	-0.01	15.0	1.41	13.6
24	24.4	1362.9	-3.8	2.7	-0.01	13.3	1.43	13.6
25	25.4	1203.3	-1.8	2.4	-0.00	11.9	1.44	13.5
Absolute	3.0			10.1			(T = 24.9 ms)	
	8.1				-3.03		(T = 34.5 ms)	

CASE METHOD

J =	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
RP	2919	2266	1613	961	308	0	0	0	0	0
RX	3063	2526	2132	1770	1446	1409	1403	1401	1398	1395
RU	2919	2266	1613	961	308	0	0	0	0	0

RAU = 1372 (kN); RA2 = 1749 (kN)

Current CAPWAP Ru = 1557 (kN); Corresponding J(RP)= 0.21; J(RX) = 0.37

VMX m/s	TVP ms	VT1*Z kN	FT1 kN	FMX kN	DMX mm	DFN mm	SET mm	EMX kJ	QUS kN	KEB kN/mm
0.99	23.62	4533	4914	4952	13.5	5.5	5.5	31.0	3257	63

PILE PROFILE AND PILE MODEL

Depth m	Area m^2	E-Modulus MPa	Spec. Weight kN/m^3	Perim. m
0.0	0.50	34473.8	23.563	2.51
25.4	0.50	34473.8	23.563	2.51

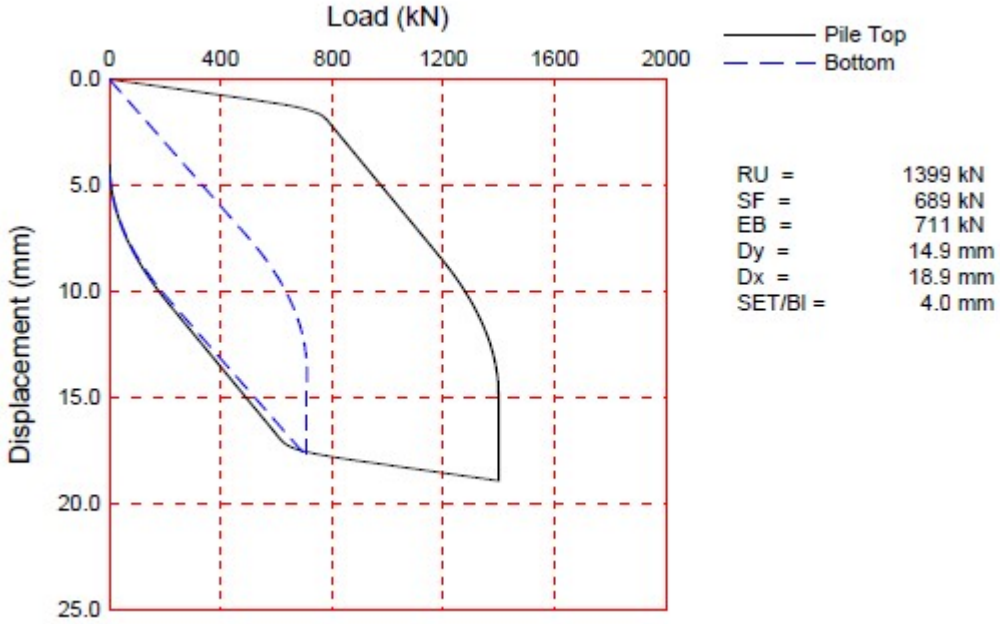
Toe Area 0.50 m^2

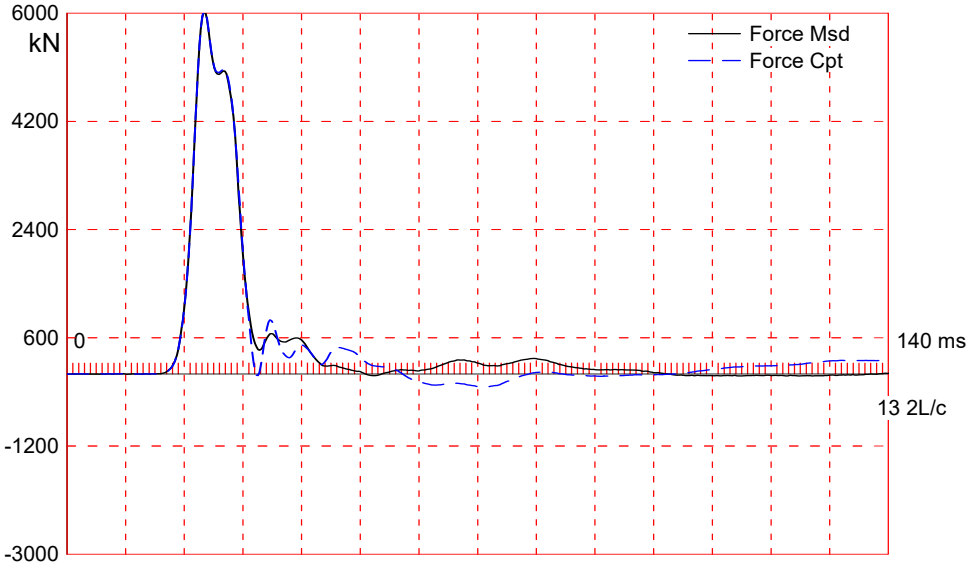
Segmnt Number	Dist. B.G. m	Impedance kN/m/s	Imped. Change %	Tension Slack mm	Tension Eff.	Compression Slack mm	Compression Eff.	Perim. m	Wave Speed m/s
1	1.0	4574.8	0.0	0.00	0.000	-0.00	0.000	2.51	4000.0
2	2.0	4613.4	0.8	0.00	0.000	-0.00	0.000	2.51	4000.0
3	3.0	4610.9	0.8	0.00	0.000	-0.00	0.000	2.51	4000.0
4	4.1	4603.9	0.6	0.00	0.000	-0.00	0.000	2.51	4000.0
5	5.1	4678.1	2.3	0.00	0.000	-0.00	0.000	2.51	4000.0
6	6.1	4761.2	4.1	0.00	0.000	-0.00	0.000	2.51	4000.0
7	7.1	4872.2	6.5	0.00	0.000	-0.00	0.000	2.51	4000.0
8	8.1	4951.4	8.2	0.00	0.000	-0.00	0.000	2.51	4000.0
9	9.1	4978.9	8.8	0.00	0.000	-0.00	0.000	2.51	4000.0
10	10.2	4942.9	8.0	0.00	0.000	-0.00	0.000	2.51	4000.0
11	11.2	4843.0	5.9	0.00	0.000	-0.00	0.000	2.51	4000.0
12	12.2	4834.8	5.7	0.00	0.000	-0.00	0.000	2.51	4000.0
13	13.2	4866.0	6.4	0.00	0.000	-0.00	0.000	2.51	4000.0
14	14.2	4864.5	6.3	0.00	0.000	-0.00	0.000	2.51	4000.0
15	15.2	4912.6	7.4	0.00	0.000	-0.00	0.000	2.51	4000.0
16	16.3	5011.9	9.6	0.00	0.000	-0.00	0.000	2.51	4000.0
17	17.3	5065.1	10.7	0.00	0.000	-0.00	0.000	2.51	4000.0
18	18.3	5107.2	11.6	0.00	0.000	-0.00	0.000	2.51	4000.0
19	19.3	5130.3	12.1	0.00	0.000	-0.00	0.000	2.51	4000.0
20	20.3	5099.9	11.5	0.00	0.000	-0.00	0.000	2.51	4000.0
21	21.3	5008.5	9.5	0.00	0.000	-0.00	0.000	2.51	4000.0
22	22.4	4822.3	5.4	0.00	0.000	-0.00	0.000	2.51	4000.0
23	23.4	4622.1	1.0	0.00	0.000	-0.00	0.000	2.51	4000.0
24	24.4	4451.8	-2.7	0.00	0.000	-0.00	0.000	2.51	4000.0
25	25.4	4449.1	-2.7	0.00	0.000	-0.00	0.000	2.51	4000.0

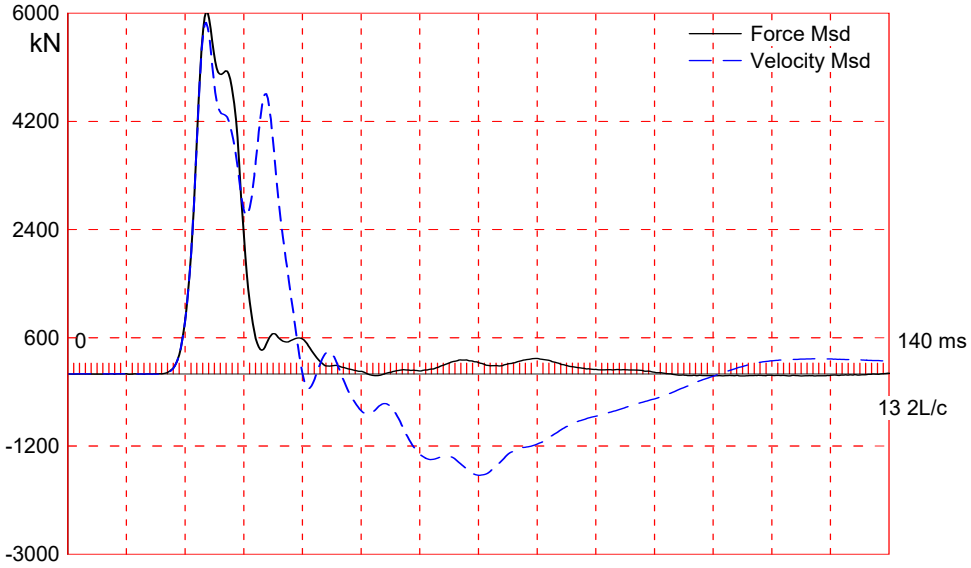
Wave Speed: Pile Top 3787.8, Elastic 3787.8, Overall 4000.0 m/s
Pile Damping 2.00 %, Time Incr 0.254 ms, 2L/c 12.7 ms
Total volume: 13.472 m^3; Volume ratio considering added impedance: 1.055

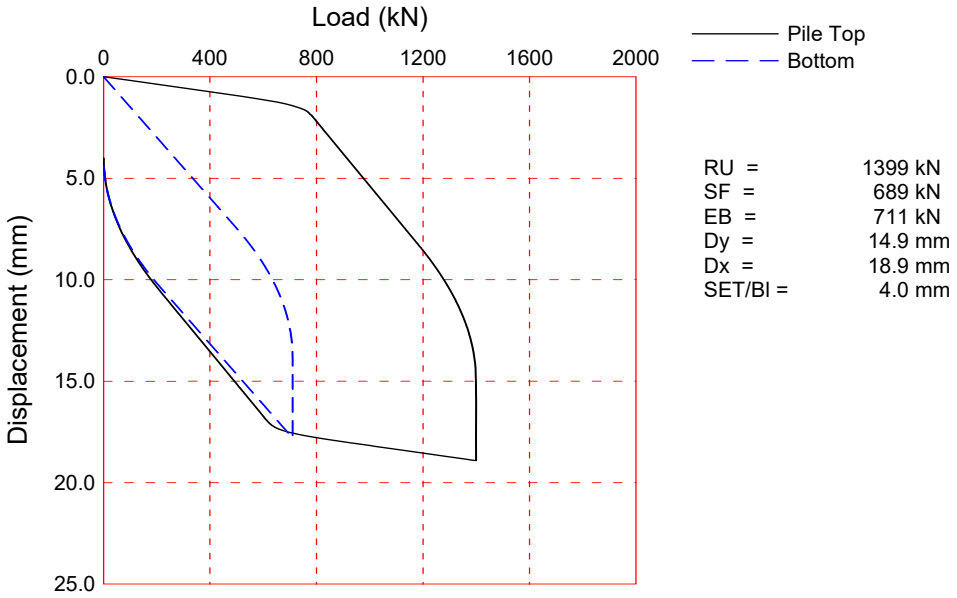
PDA-CAPWAP rezultati

2/ 20 UVRTϕ80 cm Ru = 1400 kN

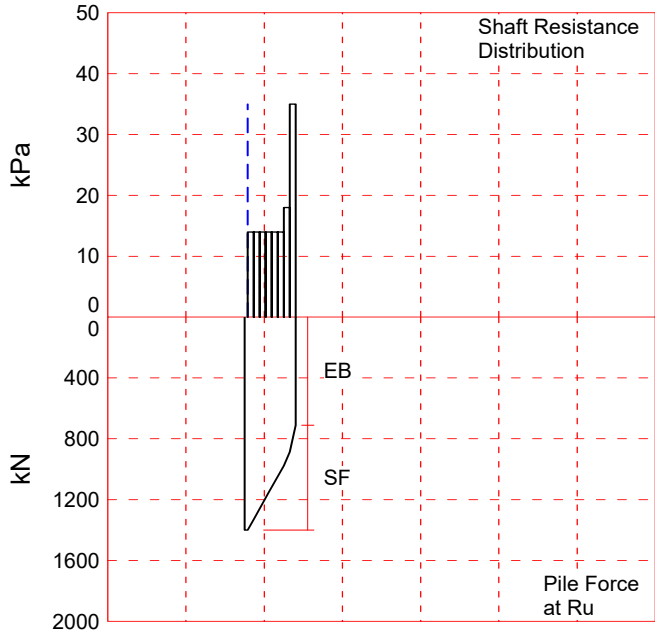








RU =	1399 kN
SF =	689 kN
EB =	711 kN
Dy =	14.9 mm
Dx =	18.9 mm
SET/Bl =	4.0 mm



Length b. Sensors	17.0 m
Embedment	16.0 m
Top Area	0.50 m^2
End Bearing Area	0.50 m^2
Top Perimeter	2.51 m
Top E-Modulus	34474 MPa
Top Spec. Weight	23.6 kN/m^3
Top Wave Spd.	3788 m/s
Overall W.S.	3900 m/s
Match Quality	6.26
Top Compr. Stress	12.1 MPa
Max Compr. Stress	12.3 MPa
Max Tension Stress	-1.17 MPa
Avg. Shaft Quake	1.0 mm
Toe Quake	10.6 mm
Avg. Shaft Smith Dpg.	1.78 s/m
Toe Smith Damping	1.57 s/m

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About the CAPWAP Results

The CAPWAP program performs a signal matching or reverse analysis based on measurements taken on a deep foundation under an impact load. The program is based on a one-dimensional mathematical model. Under certain conditions, the model only crudely approximates the often complex dynamic situations.

The CAPWAP analysis relies on the input of accurately measured dynamic data plus additional parameters describing pile and soil behavior. If the field measurements of force and velocity are incorrect or were taken under inappropriate conditions (e.g., at an inappropriate time or with too much or too little energy) or if the input pile model is incorrect, then the solution cannot represent the actual soil behavior.

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CAPWAP is also used to evaluate driving stresses along the length of the pile. However, it should be understood that the analysis is one dimensional and does not take into account bending effects or local contact stresses at the pile toe.

Furthermore, if the user of this software was not able to produce a solution with satisfactory signal "match quality" (MQ), then the associated CAPWAP results may be unreliable. There is no absolute scale for solution acceptability but solutions with MQ above 5 are generally considered less reliable than those with lower MQ values and every effort should be made to improve the analysis, for example, by getting help from other independent experts.

Considering the CAPWAP model limitations, the nature of the input parameters, the complexity of the analysis procedure, and the need for a responsible application of the results to actual construction projects, it is recommended that at least one static load test be performed on sites where little experience exists with dynamic behavior of the soil resistance or when the experience of the analyzing engineer with both program use and result application is limited.

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The CAPWAP analysis software is one of many means by which the capacity of a deep foundation can be assessed. The engineer performing the analysis is responsible for proper software application and the analysis results. Pile Dynamics accepts no liability whatsoever of any kind for the analysis solution and/or the application of the analysis result.

CAPWAP SUMMARY RESULTS

Total CAPWAP Capacity: 1399.4; along Shaft 688.6; at Toe 710.8 kN

Soil Sgmnt No.	Dist. Below Gages m	Depth Below Grade m	Ru kN	Force in Pile kN	Sum of Ru kN	Unit Resist. (Depth) kN/m	Unit Resist. (Area) kPa
				1399.4			
1	3.0	2.0	70.4	1329.0	70.4	35	14
2	5.0	4.0	70.4	1258.6	140.7	35	14
3	7.0	6.0	70.4	1188.3	211.1	35	14
4	9.0	8.0	70.4	1117.9	281.5	35	14
5	11.0	10.0	70.4	1047.5	351.9	35	14
6	13.0	12.0	70.4	977.2	422.2	35	14
7	15.0	14.0	90.5	886.7	512.7	45	18
8	17.0	16.0	175.9	710.8	688.6	88	35
Avg. Shaft			86.1			43	17
Toe			710.8				1414

Soil Model Parameters/Extensions		Shaft	Toe
Smith Damping Factor		1.78	1.57
Quake	(mm)	1.0	10.6
Case Damping Factor		0.27	0.24
Damping Type		Sm+Visc	Sm+Visc
Unloading Quake	(% of loading quake)	30	101
Reloading Level	(% of Ru)	100	100
Unloading Level	(% of Ru)	0	
Resistance Gap (included in Toe Quake)	(mm)		0.0
Soil Plug Weight	(kN)		19.525

CAPWAP match quality = 6.26 (Wave Up Match) ; RSA = 0
Observed: Final Set = 4.0 mm; Blow Count = 250 b/m
Computed: Final Set = 8.9 mm; Blow Count = 112 b/m

Transducer F3 (370A) CAL: 93.2; RF: 1.00; F4 (371A) CAL: 94.0; RF: 1.00
F7 (X139) CAL: 91.3; RF: 1.00; F8 (T609) CAL: 141.3; RF: 1.00
A1 (K11170) CAL: 438; RF: 1.00; A2 (K11082) CAL: 441; RF: 1.00
A5 (K14321) CAL: 350; RF: 1.00; A6 (K14322) CAL: 359; RF: 1.00

max. Top Comp. Stress = 12.1 MPa (T= 23.8 ms, max= 1.017 x Top)
max. Comp. Stress = 12.3 MPa (Z= 3.0 m, T= 24.4 ms)
max. Tens. Stress = -1.17 MPa (Z= 4.0 m, T= 32.1 ms)
max. Energy (EMX) = 45.4 kJ; max. Measured Top Displ. (DMX)= 15.0 mm

EXTREMA TABLE

Pile Sgmnt No.	Dist. Below Gages m	max. Force kN	min. Force kN	max. Comp. Stress MPa	max. Tens. Stress MPa	max. Trnsfd. Energy kJ	max. Veloc. m/s	max. Displ. mm
1	1.0	6090.2	-229.9	12.1	-0.46	45.4	1.26	15.1
2	2.0	6144.3	-355.2	12.2	-0.71	45.4	1.25	15.1
3	3.0	6196.7	-415.8	12.3	-0.83	45.4	1.24	15.1
4	4.0	6023.2	-587.2	12.0	-1.17	42.5	1.23	15.0
5	5.0	6070.3	-468.8	12.1	-0.93	42.5	1.22	15.0
6	6.0	5885.0	-428.4	11.7	-0.85	39.6	1.22	15.0
7	7.0	5913.4	-240.6	11.8	-0.48	39.6	1.32	15.0
8	8.0	5700.8	-211.1	11.3	-0.42	36.9	1.40	15.0
9	9.0	5676.3	-213.8	11.3	-0.43	36.8	1.47	15.0
10	10.0	5375.5	-179.9	10.7	-0.36	34.0	1.51	15.0
11	11.0	5240.6	-177.3	10.4	-0.35	34.0	1.54	15.0
12	12.0	4836.0	-141.2	9.6	-0.28	31.2	1.55	15.0
13	13.0	4599.3	-136.1	9.2	-0.27	31.2	1.55	15.0
14	14.0	4034.5	-97.4	8.0	-0.19	28.2	1.58	14.9
15	15.0	3634.0	-94.4	7.2	-0.19	28.2	1.66	14.9
16	16.0	2823.4	-50.7	5.6	-0.10	24.4	1.75	14.9
17	17.0	2236.7	-53.9	4.4	-0.11	16.8	1.80	14.8
Absolute	3.0			12.3			(T = 24.4 ms)	
	4.0				-1.17		(T = 32.1 ms)	

CASE METHOD

J =	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
RP	4180	3410	2639	1869	1099	329	0	0	0	0
RX	4180	3410	2639	2111	1756	1570	1396	1229	1065	903
RU	4180	3410	2639	1869	1099	329	0	0	0	0

RAU = 541 (kN); RA2 = 687 (kN)

Current CAPWAP Ru = 1399 (kN); Corresponding J(RP)= 0.36; J(RX) = 0.60

VMX m/s	TVP ms	VT1*Z kN	FT1 kN	FMX kN	DMX mm	DFN mm	SET mm	EMX kJ	QUS kN	KEB kN/mm
1.28	23.59	5865	6016	6041	15.0	6.1	4.0	45.5	4795	67

PILE PROFILE AND PILE MODEL

Depth m	Area m^2	E-Modulus MPa	Spec. Weight kN/m^3	Perim. m
0.0	0.50	34473.8	23.563	2.51
17.0	0.50	34473.8	23.563	2.51

Toe Area 0.50 m^2

Top Segment Length 1.00 m, Top Impedance 4575 kN/m/s

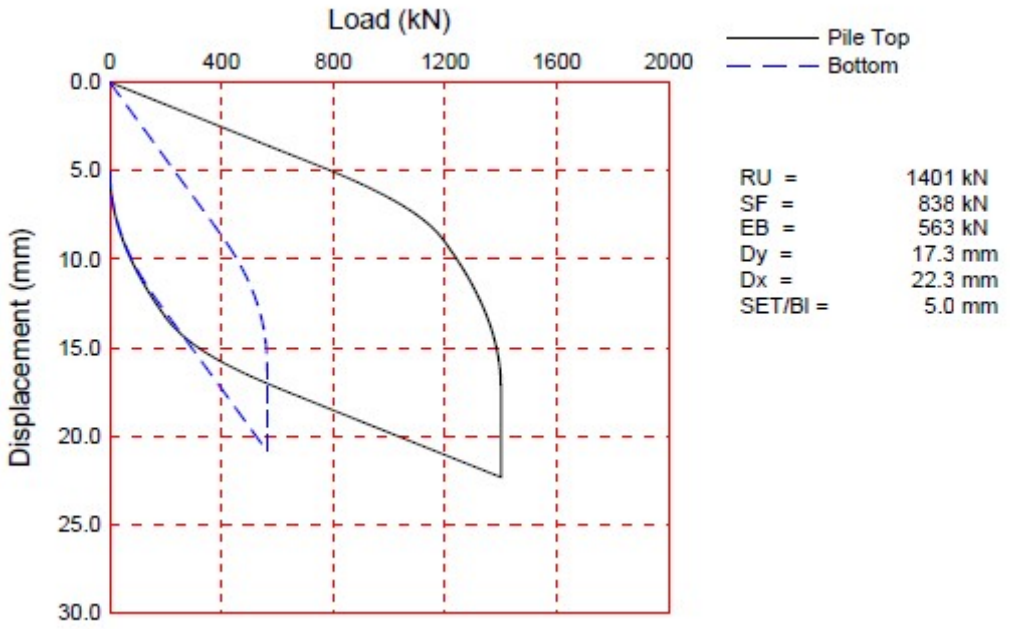
Wave Speed: Pile Top 3787.8, Elastic 3787.8, Overall 3900.0 m/s
Pile Damping 2.00 %, Time Incr 0.256 ms, 2L/c 8.7 ms
Total volume: 8.545 m^3; Volume ratio considering added impedance: 1.000

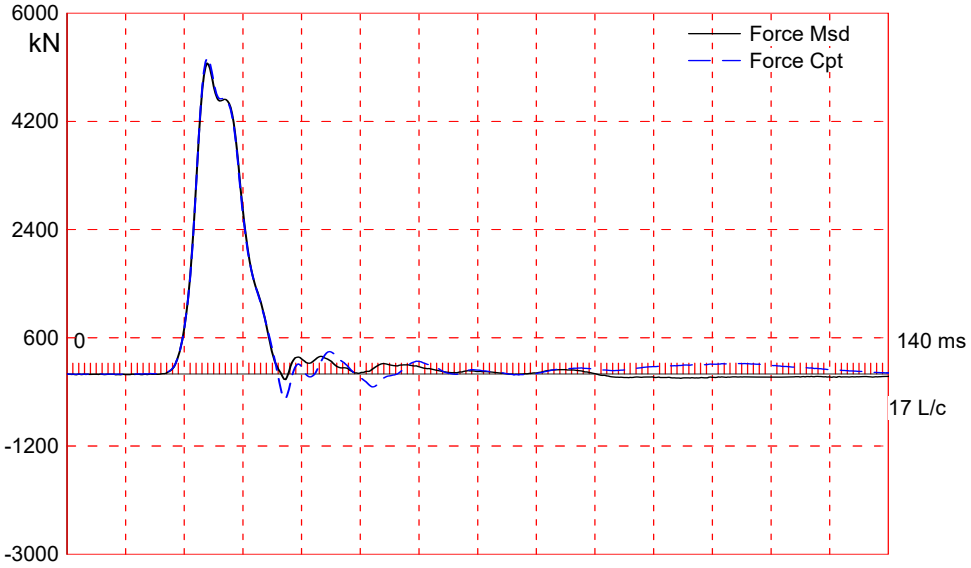
User has agreed with following statement:

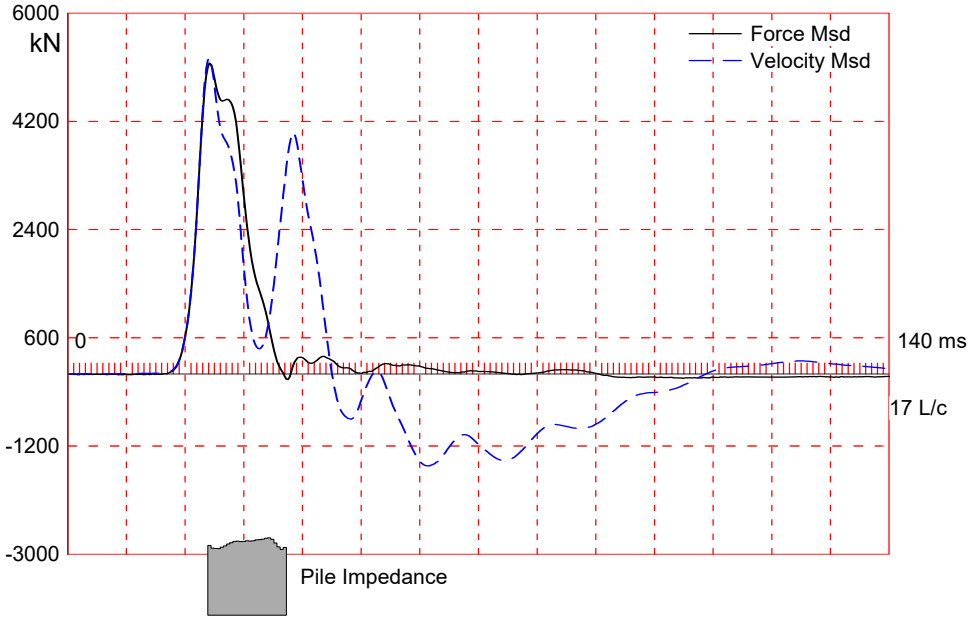
Match quality is one way to judge the reliability of the CAPWAP result. The present analysis solution produces a less than normal match quality (Match quality number greater than 5) which indicates a less than normal quality result. The user hereby acknowledges that he/she has everything done, including peer review, to assure that this is the best possible result for the given data set and pile properties. Pile Dynamics recommends that the user applies the results with caution.

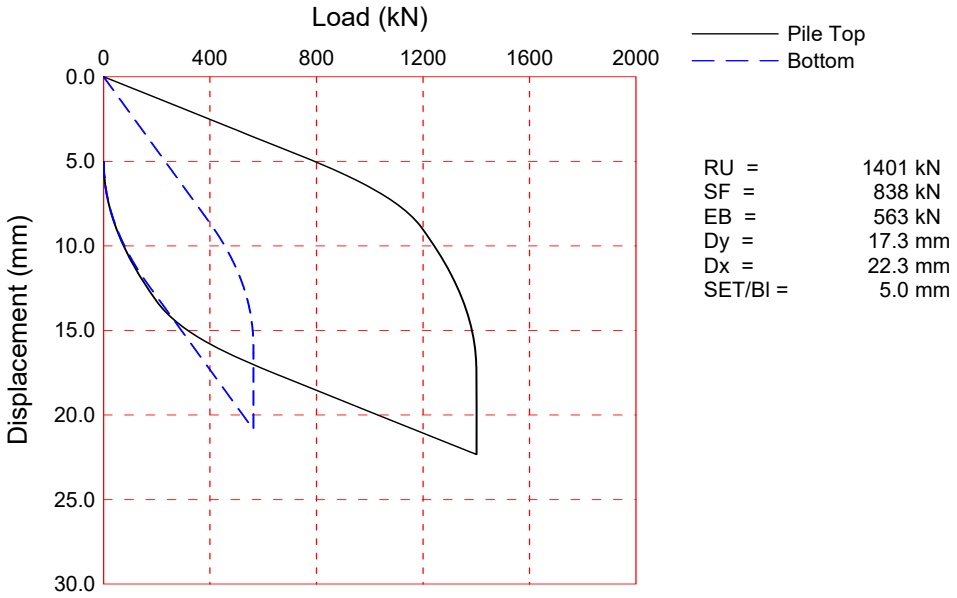
PDA-CAPWAP rezultati

3/ 55 UVRTϕ80 cm Ru = 1401 kN

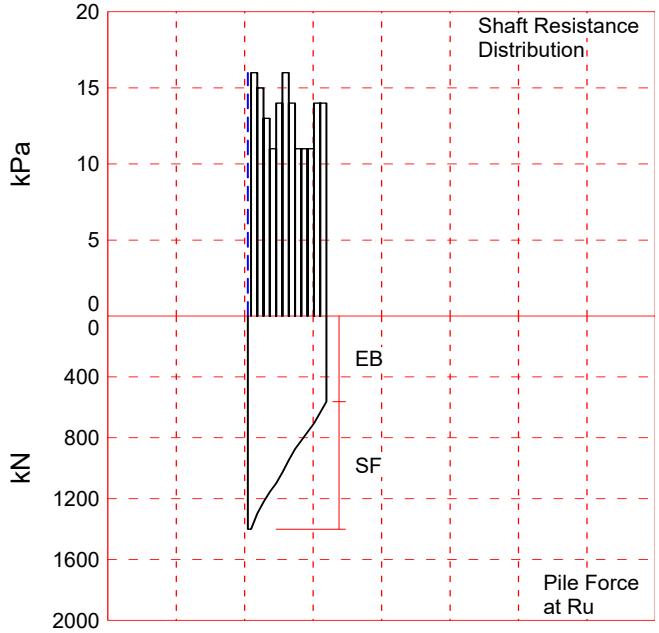








RU =	1401 kN
SF =	838 kN
EB =	563 kN
Dy =	17.3 mm
Dx =	22.3 mm
SET/Bl =	5.0 mm



Length b. Sensors	25.4 m
Embedment	24.9 m
Top Area	0.50 m^2
End Bearing Area	0.50 m^2
Top Perimeter	2.51 m
Top E-Modulus	34474 MPa
Top Spec. Weight	23.6 kN/m^3
Top Wave Spd.	3788 m/s
Overall W.S.	3763 m/s
Match Quality	3.09
Top Compr. Stress	10.6 MPa
Max Compr. Stress	10.8 MPa
Max Tension Stress	-3.54 MPa
Avg. Shaft Quake	6.4 mm
Toe Quake	12.2 mm
Avg. Shaft Smith Dpg.	1.31 s/m
Toe Smith Damping	1.36 s/m

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About the CAPWAP Results

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The CAPWAP analysis relies on the input of accurately measured dynamic data plus additional parameters describing pile and soil behavior. If the field measurements of force and velocity are incorrect or were taken under inappropriate conditions (e.g., at an inappropriate time or with too much or too little energy) or if the input pile model is incorrect, then the solution cannot represent the actual soil behavior.

Generally the CAPWAP analysis is used to estimate the axial compressive pile capacity and the soil resistance distribution. The long-term capacity is best evaluated with restrike tests since they incorporate soil strength changes (set-up gains or relaxation losses) that occur after installation. The calculated load settlement graph does not consider creep or long term consolidation settlements. When uplift is a controlling factor in the design, use of the CAPWAP results to assess uplift capacity should be made only after very careful analysis of only good measurement quality, and further used only with longer pile lengths and with nominally higher safety factors.

CAPWAP is also used to evaluate driving stresses along the length of the pile. However, it should be understood that the analysis is one dimensional and does not take into account bending effects or local contact stresses at the pile toe.

Furthermore, if the user of this software was not able to produce a solution with satisfactory signal "match quality" (MQ), then the associated CAPWAP results may be unreliable. There is no absolute scale for solution acceptability but solutions with MQ above 5 are generally considered less reliable than those with lower MQ values and every effort should be made to improve the analysis, for example, by getting help from other independent experts.

Considering the CAPWAP model limitations, the nature of the input parameters, the complexity of the analysis procedure, and the need for a responsible application of the results to actual construction projects, it is recommended that at least one static load test be performed on sites where little experience exists with dynamic behavior of the soil resistance or when the experience of the analyzing engineer with both program use and result application is limited.

Finally, the CAPWAP capacities are ultimate values. They MUST be reduced by means of an appropriate factor of safety to yield a design or working load. The selection of a factor of safety should consider the quality of the construction control, the variability of the site conditions, uncertainties in the loads, the importance of structure and other factors. The CAPWAP results should be reviewed by the Engineer of Record with consideration of applicable geotechnical conditions including, but not limited to, group effects, potential settlement from underlying compressible layers, soil resistances provided from any layers unsuitable for long term support, as well as effective stress changes due to soil surcharges, excavation or change in water table elevation.

The CAPWAP analysis software is one of many means by which the capacity of a deep foundation can be assessed. The engineer performing the analysis is responsible for proper software application and the analysis results. Pile Dynamics accepts no liability whatsoever of any kind for the analysis solution and/or the application of the analysis result.

CAPWAP SUMMARY RESULTS

Total CAPWAP Capacity: 1400.8; along Shaft 837.9; at Toe 563.0 kN

Soil Sgmnt No.	Dist. Below Gages m	Depth Below Grade m	Ru kN	Force in Pile kN	Sum of Ru kN	Unit Resist. (Depth) kN/m	Unit Resist. (Area) kPa
				1400.8			
1	3.0	2.5	102.5	1298.4	102.5	40	16
2	5.1	4.6	76.6	1221.8	179.1	38	15
3	7.1	6.6	66.4	1155.4	245.5	33	13
4	9.1	8.6	56.2	1099.2	301.6	28	11
5	11.2	10.7	71.5	1027.7	373.1	35	14
6	13.2	12.7	81.7	946.0	454.8	40	16
7	15.2	14.7	71.5	874.5	526.3	35	14
8	17.3	16.8	56.2	818.3	582.5	28	11
9	19.3	18.8	56.2	762.1	638.7	28	11
10	21.3	20.8	56.2	706.0	694.9	28	11
11	23.4	22.9	71.5	634.5	766.4	35	14
12	25.4	24.9	71.5	563.0	837.9	35	14
Avg. Shaft			69.8			34	13
Toe			563.0				1120

Soil Model Parameters/Extensions		Shaft	Toe
Smith Damping Factor		1.31	1.36
Quake	(mm)	6.4	12.2
Case Damping Factor		0.24	0.17
Damping Type		Viscous	Viscous
Unloading Quake	(% of loading quake)	119	100
Reloading Level	(% of Ru)	100	100
Unloading Level	(% of Ru)	0	
Soil Plug Weight	(kN)		6.276
Soil Support Dashpot		0.100	0.000
Soil Support Weight	(kN)	25.50	0.00

CAPWAP match quality = 3.09 (Wave Up Match) ; RSA = 0
Observed: Final Set = 5.0 mm; Blow Count = 200 b/m
Computed: Final Set = 5.1 mm; Blow Count = 195 b/m

Transducer F3 (370A) CAL: 93.2; RF: 1.00; F4 (371A) CAL: 94.0; RF: 1.00
F7 (X139) CAL: 91.3; RF: 1.00; F8 (T609) CAL: 141.3; RF: 1.00
A1 (K11170) CAL: 438; RF: 1.00; A2 (K11082) CAL: 441; RF: 1.00
A5 (K14321) CAL: 350; RF: 1.00; A6 (K14322) CAL: 359; RF: 1.00

max. Top Comp. Stress = 10.6 MPa (T= 24.4 ms, max= 1.024 x Top)
max. Comp. Stress = 10.8 MPa (Z= 3.0 m, T= 24.9 ms)
max. Tens. Stress = -3.54 MPa (Z= 10.2 m, T= 35.4 ms)
max. Energy (EMX) = 33.3 kJ; max. Measured Top Displ. (DMX)= 13.8 mm

EXTREMA TABLE

Pile Sgmnt No.	Dist. Below Gages m	max. Force kN	min. Force kN	max. Comp. Stress MPa	max. Tens. Stress MPa	max. Trnsfd. Energy kJ	max. Veloc. m/s	max. Displ. mm
1	1.0	5309.1	-611.2	10.6	-1.22	33.3	1.12	14.1
2	2.0	5372.3	-797.4	10.7	-1.59	33.2	1.10	14.0
4	4.1	5329.8	-1313.4	10.6	-2.61	31.9	1.07	13.9
6	6.1	5298.2	-1620.6	10.5	-3.22	30.9	1.05	13.8
8	8.1	5255.6	-1751.0	10.5	-3.48	29.9	1.04	13.7
9	9.1	5288.0	-1728.2	10.5	-3.44	29.7	1.03	13.7
10	10.2	5231.1	-1777.3	10.4	-3.54	28.8	1.02	13.7
11	11.2	5263.3	-1682.3	10.5	-3.35	28.5	1.01	13.7
12	12.2	5178.3	-1664.6	10.3	-3.31	27.3	1.01	13.7
13	13.2	5196.5	-1467.3	10.3	-2.92	26.7	1.00	13.8
14	14.2	5074.2	-1351.2	10.1	-2.69	25.1	1.08	13.8
15	15.2	5055.2	-1189.9	10.1	-2.37	24.3	1.18	13.8
16	16.3	4886.2	-1210.3	9.7	-2.41	22.5	1.25	13.9
17	17.3	4779.6	-1107.3	9.5	-2.20	22.4	1.30	13.9
18	18.3	4542.0	-1058.0	9.0	-2.10	21.1	1.34	13.9
19	19.3	4340.1	-889.0	8.6	-1.77	21.1	1.36	13.9
20	20.3	3979.5	-754.0	7.9	-1.50	19.7	1.37	13.9
21	21.3	3658.4	-490.8	7.3	-0.98	19.7	1.39	13.9
22	22.4	3188.7	-264.5	6.3	-0.53	18.3	1.46	13.9
23	23.4	2741.1	-25.7	5.5	-0.05	18.3	1.53	13.9
24	24.4	2123.9	-15.7	4.2	-0.03	16.5	1.59	13.9
25	25.4	1649.3	-20.3	3.3	-0.04	14.8	1.61	13.8
Absolute	3.0			10.8			(T =	24.9 ms)
	10.2				-3.54		(T =	35.4 ms)

CASE METHOD

J =	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
RP	3317	2604	1892	1179	466	0	0	0	0	0
RX	3317	2604	1894	1502	1296	1125	1097	1093	1090	1090
RU	3317	2604	1892	1179	466	0	0	0	0	0

RAU = 1090 (kN); RA2 = 1338 (kN)

Current CAPWAP Ru = 1401 (kN); Corresponding J(RP)= 0.27; J(RX) = 0.35

VMX m/s	TVP ms	VT1*Z kN	FT1 kN	FMX kN	DMX mm	DFN mm	SET mm	EMX kJ	QUS kN	KEB kN/mm
1.15	24.14	5263	5180	5180	13.8	4.9	5.0	34.1	3627	46

PILE PROFILE AND PILE MODEL

Depth m	Area m^2	E-Modulus MPa	Spec. Weight kN/m^3	Perim. m
0.0	0.50	34473.8	23.563	2.51
25.4	0.50	34473.8	23.563	2.51

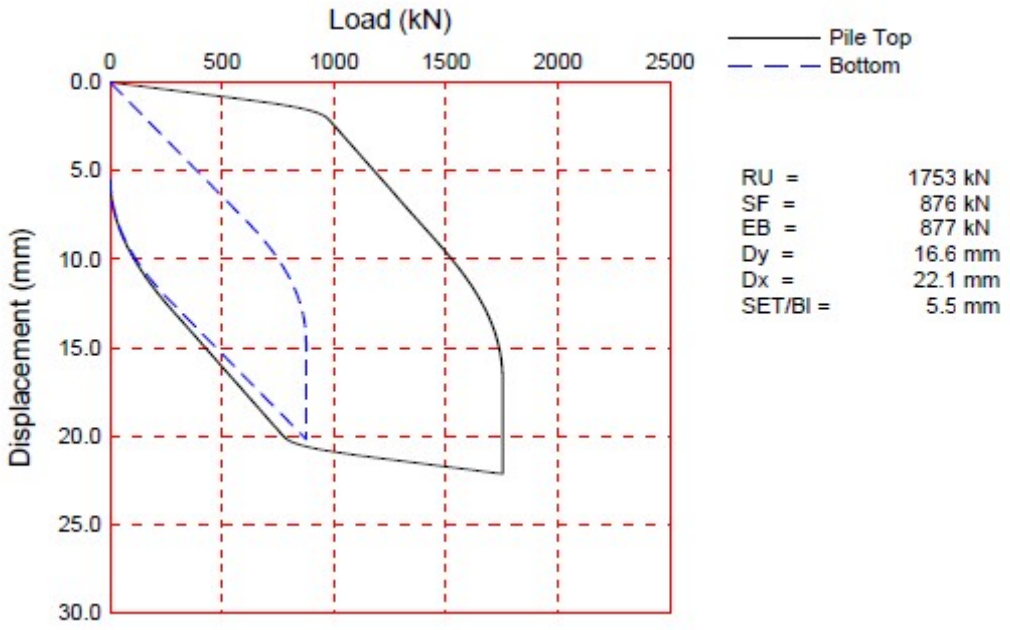
Toe Area 0.50 m^2

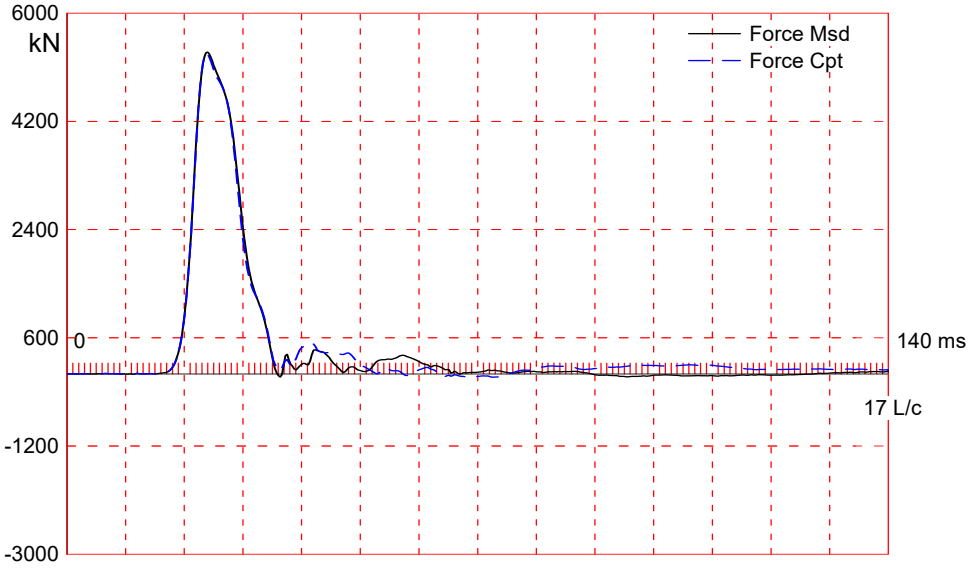
Segmnt Number	Dist. B.G. m	Impedance kN/m/s	Imped. Change %	Tension Slack mm	Tension Eff.	Compression Slack mm	Compression Eff.	Perim. m	Wave Speed m/s
1	1.0	4574.8	0.0	0.00	0.000	-0.00	0.000	2.51	3787.8
2	2.0	4401.3	-3.8	0.00	0.000	-0.00	0.000	2.51	3787.8
3	3.0	4374.6	-4.4	0.00	0.000	-0.00	0.000	2.51	3787.8
4	4.1	4365.2	-4.6	0.00	0.000	-0.00	0.000	2.51	3787.8
5	5.1	4455.9	-2.6	0.00	0.000	-0.00	0.000	2.51	3787.8
6	6.1	4548.6	-0.6	0.00	0.000	-0.00	0.000	2.51	3787.8
7	7.1	4670.4	2.1	0.00	0.000	-0.00	0.000	2.51	3787.8
8	8.1	4756.8	4.0	0.00	0.000	-0.00	0.000	2.51	3787.8
9	9.1	4838.6	5.8	0.00	0.000	-0.00	0.000	2.51	3787.8
10	10.2	4864.6	6.3	0.00	0.000	-0.00	0.000	2.51	3787.8
11	11.2	4828.0	5.5	0.00	0.000	-0.00	0.000	2.51	3787.8
12	12.2	4835.2	5.7	0.00	0.000	-0.00	0.000	2.51	3787.8
13	13.2	4880.1	6.7	0.00	0.000	-0.00	0.000	2.51	3787.8
14	14.2	4860.3	6.2	0.00	0.000	-0.00	0.000	2.51	3787.8
15	15.2	4883.9	6.8	0.00	0.000	-0.00	0.000	2.51	3787.8
16	16.3	4946.7	8.1	0.00	0.000	-0.00	0.000	2.51	3787.8
17	17.3	4961.1	8.4	0.00	0.000	-0.00	0.000	2.51	3787.8
18	18.3	4985.3	9.0	0.00	0.000	-0.00	0.000	2.51	3787.8
19	19.3	5045.6	10.3	0.00	0.000	-0.00	0.000	2.51	3787.8
20	20.3	5068.9	10.8	0.00	0.000	-0.00	0.000	2.51	3787.8
21	21.3	4974.4	8.7	0.00	0.000	-0.00	0.000	2.51	3787.8
22	22.4	4734.6	3.5	0.00	0.000	-0.00	0.000	2.51	3787.8
23	23.4	4481.5	-2.0	0.00	0.000	-0.00	0.000	2.51	3787.8
24	24.4	4311.4	-5.8	0.00	0.000	-0.00	0.000	2.51	3787.8
25	25.4	4434.9	-3.1	0.00	0.000	-0.00	0.000	2.51	3787.8

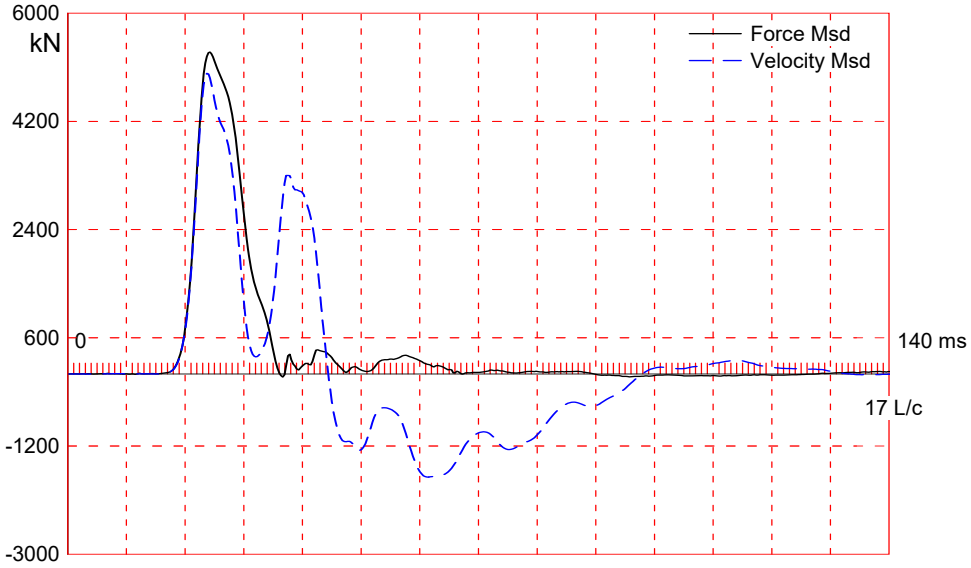
Wave Speed: Pile Top 3787.8, Elastic 3787.8, Overall 3763.0 m/s
Pile Damping 2.00 %, Time Incr 0.268 ms, 2L/c 13.5 ms
Total volume: 13.182 m^3, Volume ratio considering added impedance: 1.032

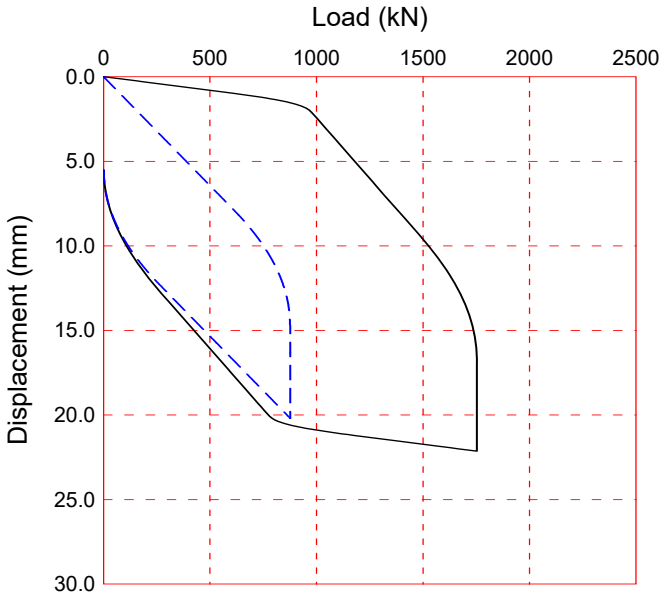
PDA-CAPWAP rezultati

4/ 51 UVRTϕ80 cm Ru = 1753 kN

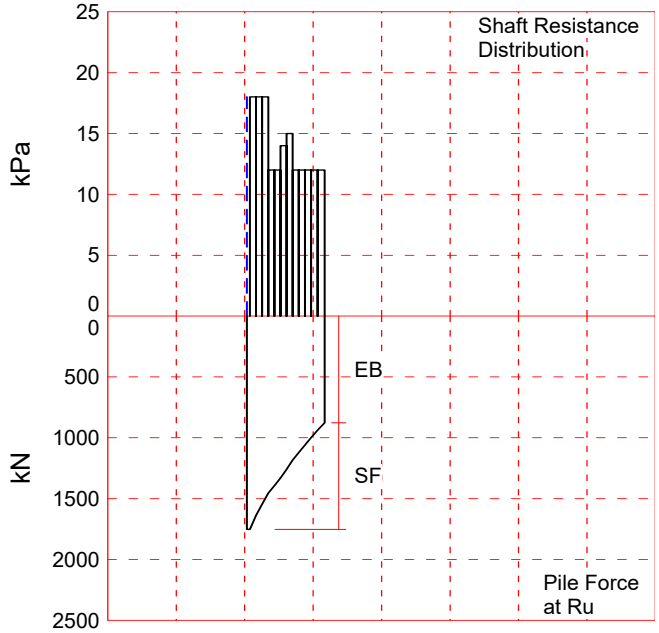








RU =	1753 kN
SF =	876 kN
EB =	877 kN
Dy =	16.6 mm
Dx =	22.1 mm
SET/Bl =	5.5 mm



Length b. Sensors	25.4 m
Embedment	24.9 m
Top Area	0.50 m^2
End Bearing Area	0.50 m^2
Top Perimeter	2.51 m
Top E-Modulus	34474 MPa
Top Spec. Weight	23.6 kN/m^3
Top Wave Spd.	3788 m/s
Overall W.S.	3900 m/s
Match Quality	3.62
Top Compr. Stress	10.7 MPa
Max Compr. Stress	10.9 MPa
Max Tension Stress	-2.51 MPa
Avg. Shaft Quake	1.1 mm
Toe Quake	11.3 mm
Avg. Shaft Smith Dpg.	1.04 s/m
Toe Smith Damping	1.33 s/m

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CAPWAP SUMMARY RESULTS

Total CAPWAP Capacity: 1752.8; along Shaft 876.2; at Toe 876.6 kN

Soil Sgmnt No.	Dist. Below Gages m	Depth Below Grade m	Ru kN	Force in Pile kN	Sum of Ru kN	Unit Resist. (Depth) kN/m	Unit Resist. (Area) kPa	Quake mm
				1752.8				
1	3.0	2.5	115.3	1637.6	115.3	45	18	1.1
2	5.1	4.6	91.9	1545.6	207.2	45	18	1.0
3	7.1	6.6	91.9	1453.7	299.1	45	18	1.0
4	9.1	8.6	61.3	1392.4	360.4	30	12	1.0
5	11.2	10.7	61.3	1331.2	421.7	30	12	1.0
6	13.2	12.7	71.5	1259.7	493.2	35	14	1.0
7	15.2	14.7	76.6	1183.0	569.8	38	15	1.0
8	17.3	16.8	61.3	1121.8	631.1	30	12	1.0
9	19.3	18.8	61.3	1060.5	692.4	30	12	1.0
10	21.3	20.8	61.3	999.2	753.6	30	12	1.0
11	23.4	22.9	61.3	937.9	814.9	30	12	1.0
12	25.4	24.9	61.3	876.6	876.2	30	12	1.0
Avg. Shaft			73.0			35	14	1.1
Toe			876.6				1744	11.3

Soil Model Parameters/Extensions		Shaft	Toe
Smith Damping Factor		1.04	1.33
Case Damping Factor		0.20	0.25
Damping Type		Viscous	Viscous
Unloading Quake	(% of loading quake)	100	96
Reloading Level	(% of Ru)	100	100
Unloading Level	(% of Ru)	0	
Resistance Gap (included in Toe Quake)	(mm)		2.1
Soil Plug Weight	(kN)		6.521

CAPWAP match quality = 3.62 (Wave Up Match) ; RSA = 0
Observed: Final Set = 5.5 mm; Blow Count = 182 b/m
Computed: Final Set = 5.2 mm; Blow Count = 192 b/m

Transducer
F2 (U696) CAL: 137.9; RF: 1.00; F4 (C258) CAL: 91.0; RF: 1.00
F7 (U697) CAL: 138.2; RF: 1.00; F8 (Z155) CAL: 89.2; RF: 1.00
A1 (K1328) CAL: 370; RF: 1.00; A3 (K13541) CAL: 385; RF: 1.00
A5 (K2161) CAL: 368; RF: 1.00; A6 (K13583) CAL: 311; RF: 1.00

max. Top Comp. Stress = 10.7 MPa (T= 24.2 ms, max= 1.016 x Top)
max. Comp. Stress = 10.9 MPa (Z= 3.0 m, T= 24.7 ms)
max. Tens. Stress = -2.51 MPa (Z= 10.2 m, T= 34.9 ms)
max. Energy (EMX) = 35.5 kJ; max. Measured Top Displ. (DMX)= 13.1 mm

EXTREMA TABLE

Pile Sgmnt No.	Dist. Below Gages m	max. Force kN	min. Force kN	max. Comp. Stress MPa	max. Tens. Stress MPa	max. Trnsfd. Energy kJ	max. Veloc. m/s	max. Displ. mm
1	1.0	5372.4	-211.9	10.7	-0.42	35.5	1.08	13.0
2	2.0	5419.8	-457.3	10.8	-0.91	35.5	1.07	12.9
4	4.1	5255.3	-919.6	10.5	-1.83	33.0	1.06	12.8
6	6.1	5132.1	-1131.7	10.2	-2.25	31.0	1.04	12.6
8	8.1	5005.9	-1250.9	10.0	-2.49	29.5	1.03	12.3
9	9.1	5038.8	-1219.6	10.0	-2.43	29.4	1.02	12.2
10	10.2	4947.8	-1260.5	9.8	-2.51	28.5	1.01	12.1
11	11.2	4978.0	-1186.5	9.9	-2.36	28.2	1.00	12.0
12	12.2	4884.3	-1171.4	9.7	-2.33	27.1	1.00	11.9
13	13.2	4908.3	-1037.3	9.8	-2.06	26.8	0.99	11.8
14	14.2	4779.4	-1012.9	9.5	-2.02	25.4	0.99	11.7
15	15.2	4781.2	-910.4	9.5	-1.81	25.2	1.06	11.7
16	16.3	4606.3	-913.7	9.2	-1.82	23.6	1.14	11.7
17	17.3	4553.7	-793.7	9.1	-1.58	23.6	1.20	11.6
18	18.3	4340.8	-732.2	8.6	-1.46	22.4	1.24	11.6
19	19.3	4215.0	-553.4	8.4	-1.10	22.3	1.28	11.6
20	20.3	3891.7	-424.9	7.7	-0.85	21.0	1.30	11.5
21	21.3	3650.4	-167.6	7.3	-0.33	21.0	1.33	11.5
22	22.4	3188.6	-127.5	6.3	-0.25	19.7	1.37	11.5
23	23.4	2818.1	-117.4	5.6	-0.23	19.7	1.41	11.5
24	24.4	2281.4	-101.2	4.5	-0.20	18.4	1.44	11.4
25	25.4	1968.4	-114.4	3.9	-0.23	17.3	1.45	11.4
Absolute	3.0			10.9			(T =	24.7 ms)
	10.2				-2.51		(T =	34.9 ms)

CASE METHOD

J =	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
RP	3571	2896	2221	1546	870	195	0	0	0	0
RX	3688	3025	2362	2001	1881	1762	1657	1556	1478	1417
RU	3571	2896	2221	1546	870	195	0	0	0	0

RAU = 1101 (kN); RA2 = 1456 (kN)

Current CAPWAP Ru = 1753 (kN); Corresponding J(RP)= 0.27; J(RX) = 0.51

VMX m/s	TVP ms	VT1*Z kN	FT1 kN	FMX kN	DMX mm	DFN mm	SET mm	EMX kJ	QUS kN	KEB kN/mm
1.09	23.97	5008	5315	5361	13.1	5.2	5.5	34.9	3750	95

PILE PROFILE AND PILE MODEL

Depth m	Area m^2	E-Modulus MPa	Spec. Weight kN/m^3	Perim. m
0.0	0.50	34473.8	23.563	2.51
25.4	0.50	34473.8	23.563	2.51

Toe Area 0.50 m^2

Top Segment Length 1.02 m, Top Impedance 4575 kN/m/s

Wave Speed: Pile Top 3787.8, Elastic 3787.8, Overall 3900.0 m/s
Pile Damping 2.00 %
Total volume: 12.767 m^3; Volume ratio considering added impedance: 1.000

Time (ms)	0.0	35.0
Time Incr	0.261	0.300

PRILOGA
3 DINAMIČNI OBREMENILNI TEST - OPIS POSTOPKA

DINAMIČNI OBREMENILNI TEST (DOT)
POSTOPEK IZVEDBE

SLP d.o.o. LJUBLJANA, Ljubljana, Gorazd STRNIŠA,univ.dipl.inž.gradb.

Dinamični obremenilni test (DOT) je postopek testiranja pilota, ki je alternativa statičnemu obremenilnemu testu. Končni rezultat je statična nosilnost testiranega pilota.

Statična nosilnost pilota se določi na osnovi izvedenih meritev pilota s PDA (Pile Dynamic Analyzer) med zabijanjem in analize meritev z računalniškim programom CAPWAP.

Rezultat CAPWAP analize je statična nosilnost konice in plašča merjenega pilota.

Poleg tega pa se ob izvajanju PDA meritev pridobi še veliko informacij, ki so pomembne za uspešno izvedbo zabijanja pilotov. Ob vsakem udarcu zabijala dobimo podatke o:

- maksimalni tlačni sili v pilotu med zabijanjem
- največji natezni sili v pilotu med zabijanjem
- največjem dinamičnem in stalnem pomiku glave pilota
- ekscentričnosti udarca zabijala
- prenešeni energiji iz zabijala v pilot
- opozorila in oceno o stopnji eventualne poškodbe pilota
- statično nosilnosti pilota na osnovi približne CASE metode ,….

Če se izvajajo meritve pilota med penetriranjem pilota v zemljino se lahko zgornji rezultati meritve predstavijo v PDAPLOT diagramih, ki grafično prikazujejo spremembe količin po globini.

Če pričakujemo, da se bo nosilnost pilota čez nekaj časa po zabitju spremenila, lahko meritve po določenem času ponovimo in ugotavljamo spremembe nosilnosti pilota s časom.

Dinamični obremenilni test se izvede v dveh fazah:

A. Izvedba meritev na terenu s PDA (Pile Dynamic Analyzer)

B. Določitev statične nosilnosti pilota s CAPWAP analizo

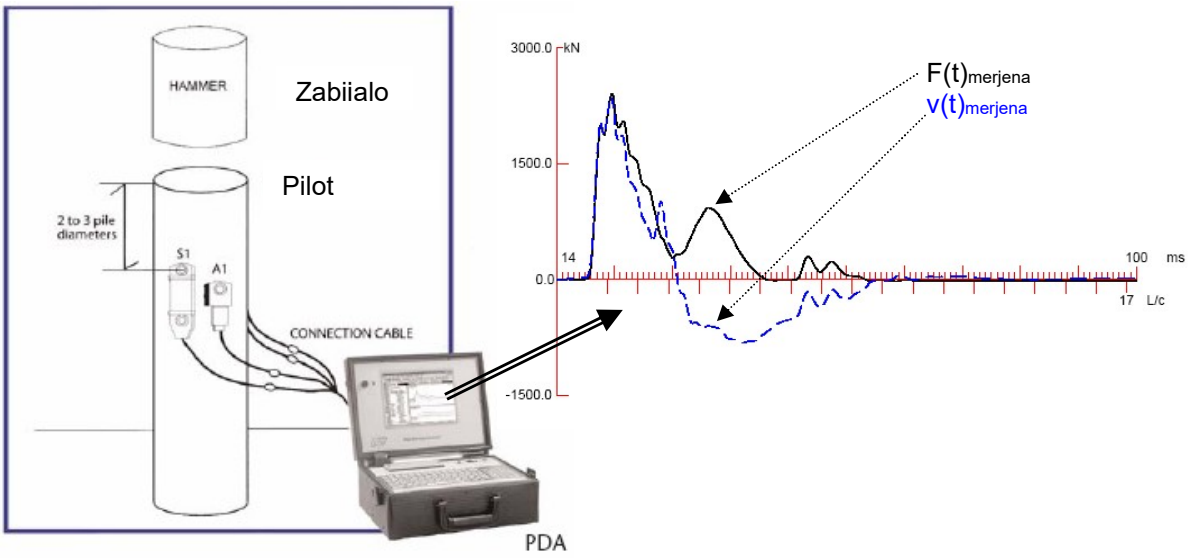
A. Izvedba meritev na terenu s PDA (Pile Dynamic Analyzer)

Dinamični preizkus nosilnosti pilota na terenu izvedemo tako, da na pilot, ki ga preizkušamo, pritrdimo senzorje osno simetrično, približno 2 premera pod glavo pilota, jih povežemo s PDA analizatorjem in pilot začnemo zabijati z ustreznim zabijalom.

Meritve se v PDA obdelajo, tako da dobimo ob vsakem udarcu zabijala na zaslonu takojšen prikaz poteka sile na glavi pilota in hitrosti pomika glave pilota ($F_{merjeno}(t)$ in $v_{merjeno}(t)$) v odvisnosti od časa in obliko ter velikost dol in gor potujočega napetostnega vala v pilotu. Vsi podatki se snemajo, da jih po zabijanju ponovno analiziramo.

Na osnovi merjene sile in hitrosti na glavi pilota lahko na terenu med zabijanjem za vsak udarec zabijala pridobimo nosilnost pilota in druge podatke o zabijanju pilota.

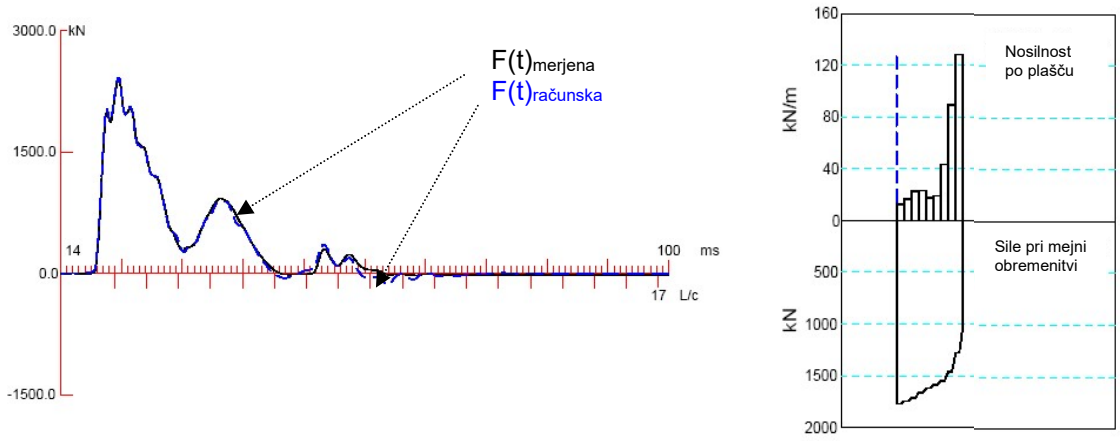
Merilci morajo biti vedno nad terenom in nad vodno gladino.



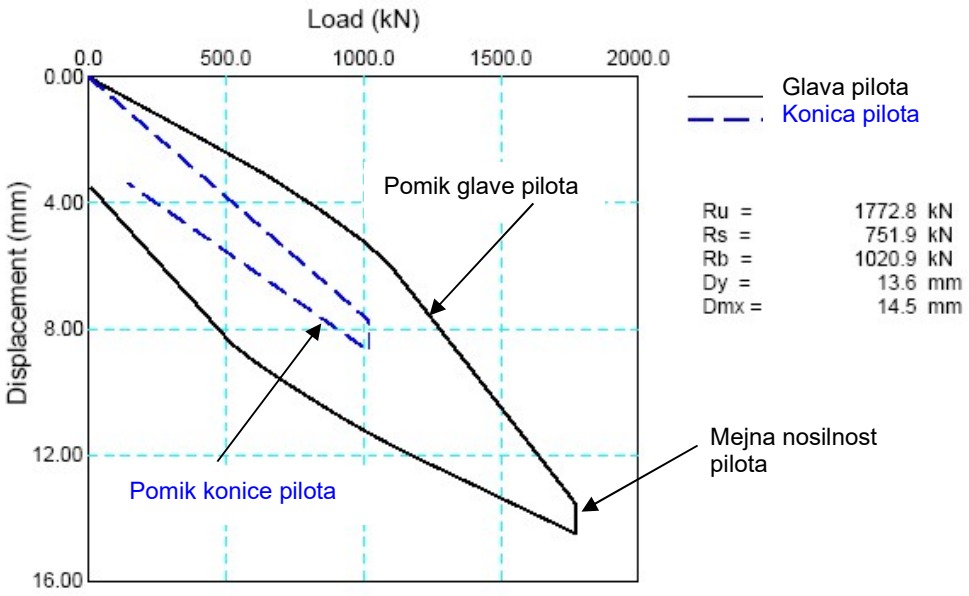
Metoda in postopek meritev je standardizirana s standardom ASTM D-4945-00 "Standard test Method for High-Strain Dynamic Testing of Piles" in definirana s priporočilom nemškega združenja geomehanikov (Recommentatin for dynamic pile tests of Technical Committee 5 of the German Geotechnical Society) v skladu s priporočilo Code EU7.

B. Določitev statične nosilnosti pilota s CAPWAP analizo

Po izvedbi terenskega dela dinamičnega obremenilnega testa se podatki za izbran udarec obdelajo na računalniku s **CAPWAP** (**CA**se **P**ile **W**ave **A**nalysis **P**rogram) programom, katerega osnova je valovna enačba. Modeliran pilot in modelirano zemljino (koeficienti dušenja zemljine in statični odpori slojev zemljine) injiciramo z eno merjenih vrednosti, naprimer merjeno hitrostjo pomika ($v_{merjena}(t)$). Rezultat valovne analize je računska krivulja sile ($F_{računska}(t)$), ki bi v primeru popolnoma točnih vhodnih podatkov za model zemljine popolnoma identična z merjeno krivuljo sile. Ker pa točnih podatkov za model pilota predvsem pa za model zemljine ne poznamo, je razlika med $F_{merjena}(t)$ in $F_{računska}(t)$) pri prvi analizi običajno velika, kar pomeni, da je naš izhodiščni model napačen. Z večkratnim spreminjanjem modela pilota, predvsem pa modela zemljine, iščemo najboljši približek med dejansko izmerjeno silo ($F_{merjeno}(t)$) in računsko silo ($F_{računska}(t)$). Z zadovoljivim približkom $F_{računska}(t) \approx F_{merjeno}(t)$ so poznane lastnosti modela zemljine (statičnega in dinamičnega dela) in s tem mejna nosilnost testiranega pilota.



S postopnim obremenjevanjem tako določenega modela pilota in zemljine dobimo graf obtežba-pomik testiranega pilota oz. računalniško simulacijo statičnega obremenilnega testa pilota.



Kaj merimo s PDA?

Z zabijalom povzročeni tlačni napetostni val potuje po kolu navzdol. Zaradi odporov zemljine se del tega vala odbija oz vrača nazaj na mersko mesto. Velikost odbitega vala je premosorazmerna z odpori zemljine ob plašču pilota in na konici pilota. S senzorji (merilci pospeškov in deformacije) lahko določimo dol potujoč val, ki ga je povzročilo zabijalo in gor potujoč val, ki nastane zaradi odpora zemljine (Celotni_odpor_zemljine= Dinamični_odpor:zemljine + Statični_odpor_zemljine). Meritve se s PDA (Pile Driving Analyzer) obdelajo, tako da dobimo ob vsakem udarcu zabijala na zaslonu takojšen prikaz poteka sile (iz meritve deformacije) in hitrosti pomika merskega mesta (iz meritve pospeška) v odvisnosti od časa in obliko ter velikost dol in gor potujočega vala. Vsi podatki se snemajo, da jih po zabijanju/testu ponovno podrobno analiziramo.

Obrazložitev:
Odpor zemljine ob plašču in konici pilota je pasiven, kar pomeni, da moramo povzročiti relativni pomik samega pilota glede na zemljino, da aktiviramo odpor zemljine. Pomik pilota povzročimo običajno z obtežbo glave pilota. Ta obtežba je lahko počasi naraščajoča, kot je pri statičnem obremenilnem testu (SOT) ali pa zelo hitra, kot je to primer pri dinamičnem obremenilnem testu (DOT). Zelo hitro obtežbo glave pilota lahko povzročimo z udarcem po glavi pilota.

Če želimo aktivirati ves odpor na konici in plašču pilota mora biti pomik pilota dovolj velik, da pride do prestriga oz. porušitve zemljine ob pilotu in pod konico pilota. V takem primeru lahko govorimo o obremenilnem preizkusu na pilotu, s katerim smo porušili statično odpornost zemljine in torej dosegli mejno oz. porušno obremenitev pilota po zemljini.

Kaj osnovna razlika med SOT in DOT?

Pri počasnem obremenjevanju (SOT) aktiviramo samo statični odpor zemljine (S), medtem ko pri hitrem obremenjevanju (DOT) aktiviramo poleg statičnega odpora zemljine tudi dinamični odpor zemljine (D). Da lahko ločimo statični odpor od celotnega odpora zemljine moramo uporabiti CAPWAP analizo.

Zakaj bi uporabili dinamični obremenilni test pilotov ?
- ◊ možnost izvedbe testa že v fazi izvedbe pilotiranja
- ◊ hitra izvedba in možnost testiranja več pilotov na dan
- ◊ cenejša izvedba kot statični test
- ◊ za testiranje se lahko uporabi enaka oprema kot za zabijanje pilotov
- ◊ možnost kontrole sumljivih pilotov
- ◊ rezultat je tudi nosilnosti konice in nosilnosti plašča pilota

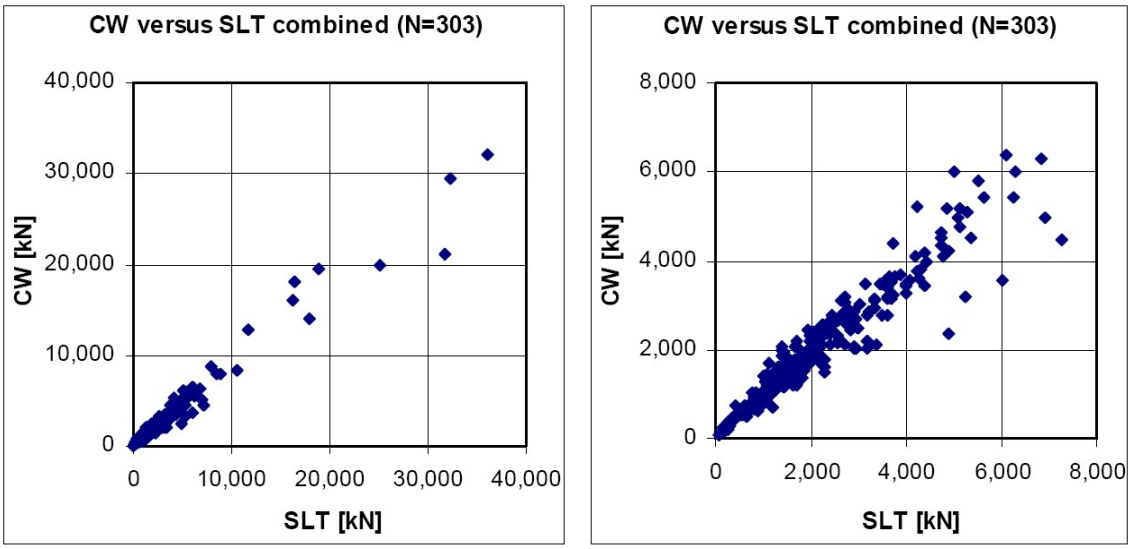
Kdaj lahko dokažemo <u>mejno</u> nosilnost pilota z dinamičnim testom?

Za izvedbo udarca po glavi pilota je potrebno uporabiti takšno zabijalo ali udarno utež, ki ob udarcu daje dovolj energije, da se ob tem lahko aktivira celoten odpor zemljine. Da zagotovo aktiviramo ves statičen odpor zemljine, moramo ob udarcu povzročiti stalno penetracijo pilota oz. pogrezek pilota več kot 2.5mm za posamezen udarec. Če pomik pilota glede na zemljino ni dovolj velik (sila na glavi pilota premajhna) je aktiviran le del mejne statične nosilnosti pilota. To seveda velja za statični in dinamični test.

Kdaj je statična nosilnost pilota določena z dinamičnim testom (DLT) in CAPWAP enaka ali podobna oz primerljiva statično nosilnostjo določeno s statičnim obremenilnim testom (SLT)?

Osnovni in pomembni pogoji so :

- ◊ Oba testa morata biti izvedena približno v enakem času po izvedbi pilota
- ◊ Pri obeh testih mora biti aktiviran celoten odpor temeljnih tal in dosežena mejna nosilnost pilota oz mejni odpor tal
- ◊ Obe meritvi morata biti izvajani z ustrezno in kalibrirano opremo, prodobljeni podatki pa morajo biti visoke kvalitete in v skladu z standardi
- ◊ Interpretacijo meritev dinamičnega obremenilnega testa DLT (CAPWAP) mora izvesti ustrezno kvalificiran inženir s certifikatom Foundation QA.



CORRELATION OF CAPWAP WITH STATIC LOAD TESTS, Garland Likins and Frank Rausche, SW2004

Ključne besede: DLT, PDA, CAPWAP, CASE, PDAPLOT,
Standard Test Method for High-Strain Dynamic Testing of Piles

PRILOGA
4 FOTOGRAFIJE



Fotografija 1: Postavljanje prosto padnega zabijalom PP-12t na pilot 25-fi80





Fotografija 2 in 3: DLT meritev z zabijalom PP-12t na pilotu 55 (levo) in 25 (desno) oba fi80

PRILOGA
5 CERTIFIKAT O USPOSOBLJENOSTI



PDCA
PILE DRIVING CONTRACTORS ASSOCIATION

Pile Dynamics, Inc.

This documents that

Gorazd Strnisa
SLP d.o.o Ljubljana

has on October 11, 2011 achieved the rank of

EXPERT

on the **Dynamic Measurement and Analysis Proficiency Test.**

The individual identified on this document demonstrated to the degree granted above an understanding of theory, data quality evaluation, interpretation and signal matching for high strain dynamic testing of deep foundations.

The ability of the individual named to provide appropriate knowledge and advice on a specific project is not implied or warranted by the Pile Driving Contractors Association or Pile Dynamics, Inc. The Pile Driving Contractors Association or Pile Dynamics, Inc. assumes no liability for foundation testing and analysis work performed by the bearer of this certificate. This certificate can be verified at www.PDAproficiencytest.com.

Steven A. Hall, Executive Director
Pile Driving Contractors Association

Garland Likins, President
Pile Dynamics, Inc

No. 190

PRILOGA

6 OPREMA IN KALIBRACIJSKI LISTI

PILE DRIVING ANALYZER Model: PDA-8G ; Ser. No.: 4982LE



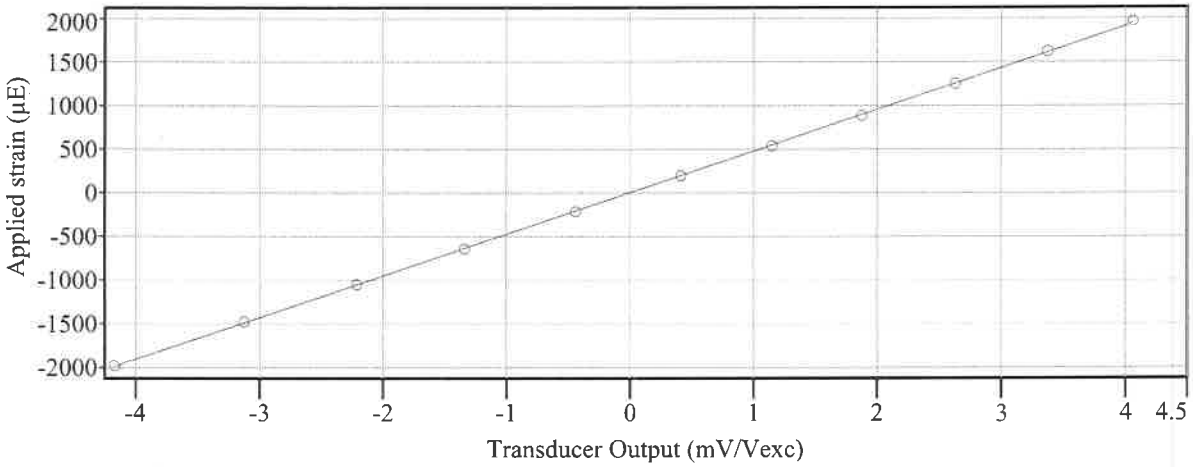
Certificate of Calibration

Pile Dynamics, Inc.
Transducer Model: PDI Strain Transducer
Serial Number: U696
PDI Gage Factor: 137.9
Mean Linear Correlation Coefficient: 0.999925

Table 1: Representative Calibration Data

Applied strain (μE)	Gage Output (mV/Vexc)	Applied strain (μE)	Gage Output (mV/Vexc)
-1981.6	-4.170	538.1	1.149
-1476.4	-3.127	885.8	1.877
-1049.9	-2.212	1253.3	2.630
-643.0	-1.339	1620.7	3.373
-216.5	-0.441	1961.9	4.059
196.9	0.410		

Calibration Curve



PDI Strain Transducer Calibration System (PDI STCS)

PDI STCS Serial Number:	1006HA
Firmware version number:	0.9.0.0
Transducer Gage Length:	3 inches (76.2mm)
Excitation Voltage for Calibration:	5.0 VDC

PDI certifies the above STCS instrument meets or exceeds published specifications and has been verified using standards and instruments whose accuracies are traceable to the National Institute of Standards and Technology (NIST), an accepted value of a natural physical constant or a ratio calibration technique.

Calibrated By: Paul Hartman Signature: Paul Hartman

PDI Gage: U696
Calibration Date: 9/7/2023 7:17:23 AM

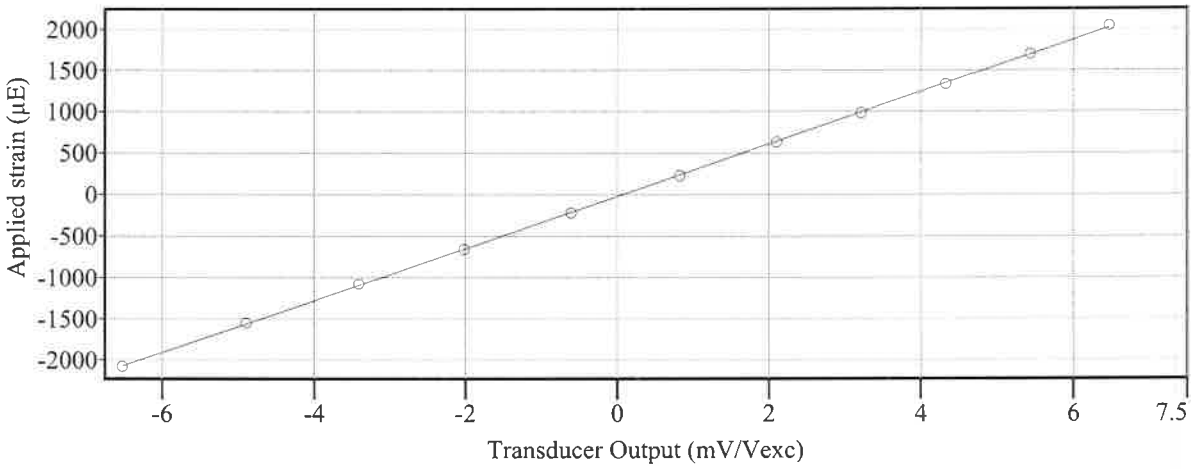
Certificate of Calibration

Pile Dynamics, Inc.
Transducer Model: PDI Strain Transducer
Serial Number: C258
PDI Gage Factor: 91.0
Mean Linear Correlation Coefficient: 0.999906

Table 1: Representative Calibration Data

Applied strain (μE)	Gage Output (mV/Vexc)	Applied strain (μE)	Gage Output (mV/Vexc)
-2080.1	-6.520	629.9	2.103
-1548.6	-4.896	984.3	3.218
-1076.1	-3.408	1329.8	4.330
-656.2	-2.014	1699.5	5.440
-218.7	-0.603	2040.7	6.469
229.7	0.824		

Calibration Curve



PDI Strain Transducer Calibration System (PDI STCS)

PDI STCS Serial Number:	1006HA
Firmware version number:	0.9.0.0
Transducer Gage Length:	3 inches (76.2mm)
Excitation Voltage for Calibration:	5.0 VDC

PDI certifies the above STCS instrument meets or exceeds published specifications and has been verified using standards and instruments whose accuracies are traceable to the National Institute of Standards and Technology (NIST), an accepted value of a natural physical constant or a ratio calibration technique.

Calibrated By: Paul Hartman Signature: Paul Hartman

PDI Gage: C258
Calibration Date: 9/7/2023 7:06:05 AM

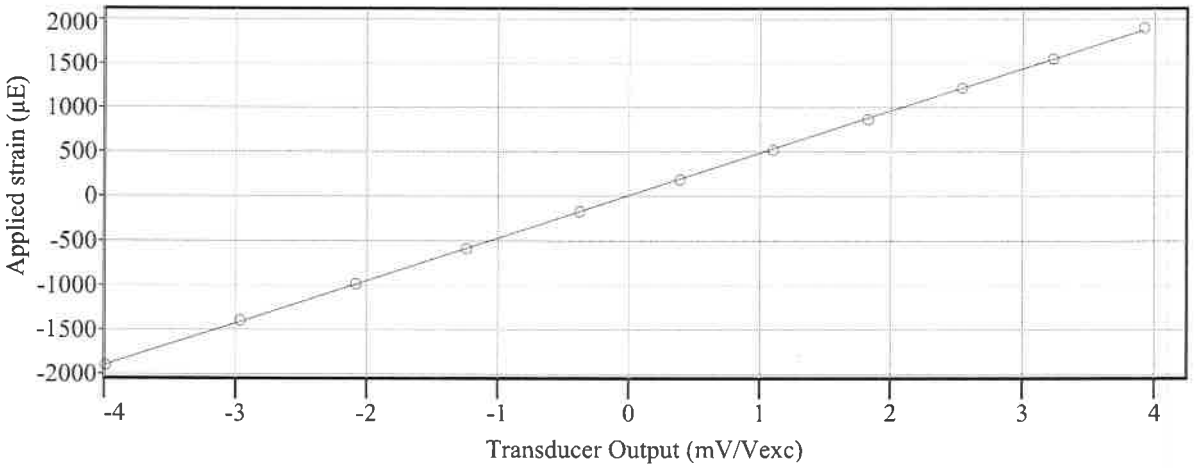
Certificate of Calibration

Pile Dynamics, Inc.
Transducer Model: PDI Strain Transducer
Serial Number: U697
PDI Gage Factor: 138.2
Mean Linear Correlation Coefficient: 0.999915

Table 1: Representative Calibration Data

Applied strain (με)	Gage Output (mV/Vexc)	Applied strain (με)	Gage Output (mV/Vexc)
-1902.9	-3.989	518.4	1.102
-1397.6	-2.968	866.1	1.826
-984.3	-2.083	1220.5	2.541
-588.4	-1.237	1555.1	3.230
-170.6	-0.376	1902.9	3.919
183.7	0.390		

Calibration Curve



PDI Strain Transducer Calibration System (PDI STCS)

PDI STCS Serial Number:	1006HA
Firmware version number:	0.9.0.0
Transducer Gage Length:	3 inches (76.2mm)
Excitation Voltage for Calibration:	5.0 VDC

PDI certifies the above STCS instrument meets or exceeds published specifications and has been verified using standards and instruments whose accuracies are traceable to the National Institute of Standards and Technology (NIST), an accepted value of a natural physical constant or a ratio calibration technique.

Calibrated By: Paul Hartman Signature: Paul Hartman

PDI Gage: U697
Calibration Date: 9/7/2023 7:09:53 AM

Pile Dynamics, Inc.

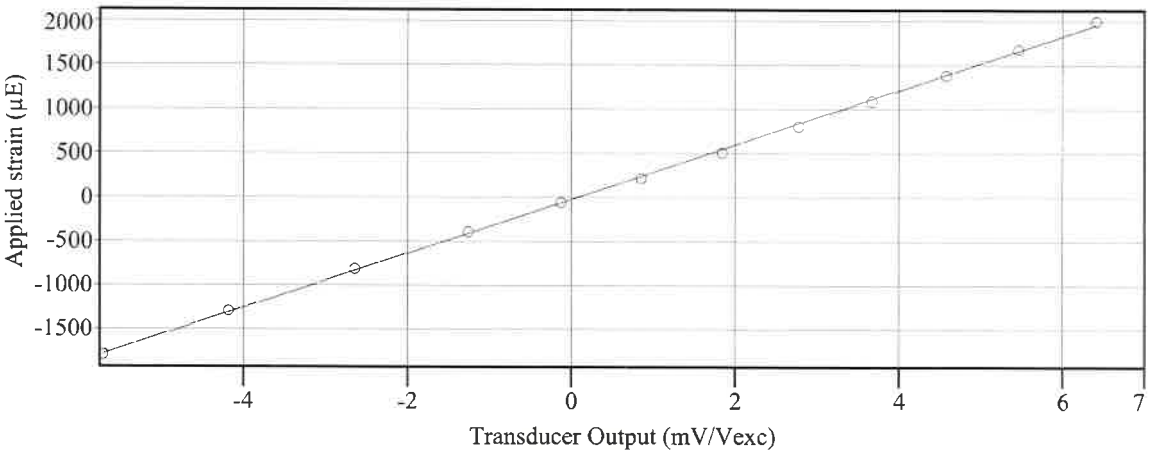
Certificate of Calibration

Pile Dynamics, Inc.
Transducer Model: PDI Strain Transducer
Serial Number: Z155
PDI Gage Factor: 89.2
Mean Linear Correlation Coefficient: 0.999535

Table 1: Representative Calibration Data

Applied strain (με)	Gage Output (mV/Vexc)	Applied strain (με)	Gage Output (mV/Vexc)
-1791.3	-5.705	505.2	1.845
-1299.2	-4.179	800.5	2.778
-820.2	-2.641	1082.7	3.666
-391.5	-1.260	1384.5	4.578
-59.1	-0.126	1679.8	5.459
214.3	0.853	1999.1	6.414

Calibration Curve



PDI Strain Transducer Calibration System (PDI STCS)

PDI STCS Serial Number:	1006HA
Firmware version number:	0.9.0.0
Transducer Gage Length:	3 inches (76.2mm)
Excitation Voltage for Calibration:	5.0 VDC

PDI certifies the above STCS instrument meets or exceeds published specifications and has been verified using standards and instruments whose accuracies are traceable to the National Institute of Standards and Technology (NIST), an accepted value of a natural physical constant or a ratio calibration technique.

Calibrated By: Paul Hartman Signature: Paul Hartman

PDI Gage: Z155
Calibration Date: OCT 2 5 2023

Pile Dynamics, Inc.

Accelerometer Calibration Certificate
Pile Dynamics, Inc.

Calibrated by Pile Dynamics, Inc.
Calibration performed on 12Sep2023

Serial No:	K1328	**Temperature:**	24.2 °C
Model:	PR	**Humidity:**	56%
Calibrated on:	Channel 3 on 8G 5161 LE		

Ref Acc 1:	72505! 1035 g's/volt	**Cal on:**	24Mar2022
Ref Acc 2:	72517! 1049 g's/volt	**Cal on:**	24Mar2022

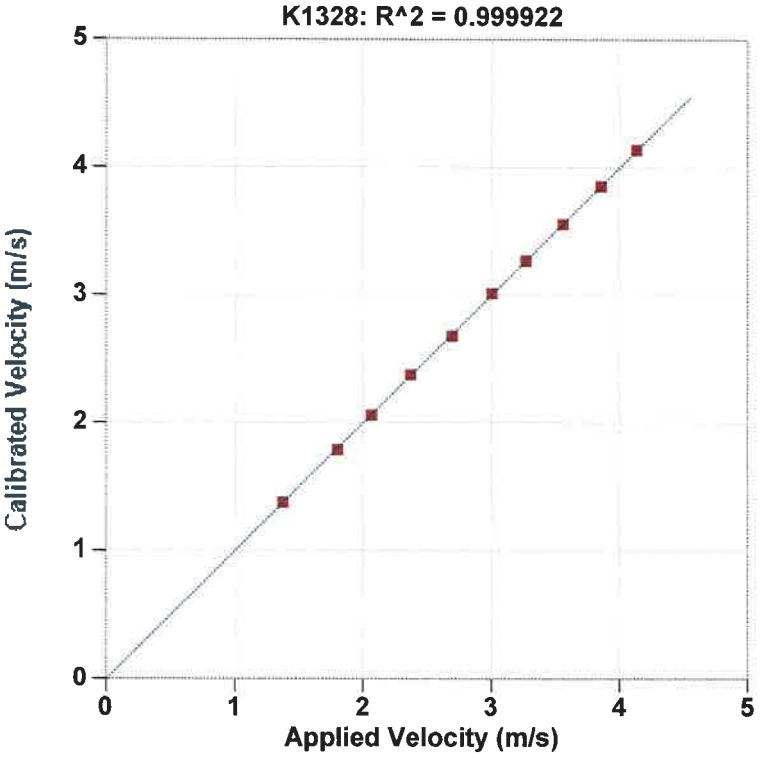
Reference accelerometer calibrations are traceable to the United States National Institute of Standards and Technology (NIST).

PDA CALIBRATION FACTOR

369.7 mv/5000g
(73.9 µv/g)
R^2: 0.999922 [Chip programmed]

Operator: William Johnson

Signed



Reference Velocity	S/N K1328 Velocity
m/s	m/s
1.377	1.379
1.802	1.788
2.065	2.060
2.373	2.379
2.693	2.683
3.002	3.015
3.270	3.270
3.561	3.557
3.855	3.853
4.133	4.140

Maximum Acceleration: 902 g's

Date printed: 12Sep2023, version: 2020.30.170 -0.78

Accelerometer Calibration Certificate
Pile Dynamics, Inc.

Calibrated by Pile Dynamics, Inc.
Calibration performed on

Serial No:	K13541	**Temperature:**	75.6 °C
Model:	PR	**Humidity:**	55%
Calibrated on:	Channel 3 on 8G 5161 LE		

Ref Acc 1:	72505! 1035 g's/volt	**Cal on:**	24Mar2022
Ref Acc 2:	72517! 1049 g's/volt	**Cal on:**	24Mar2022

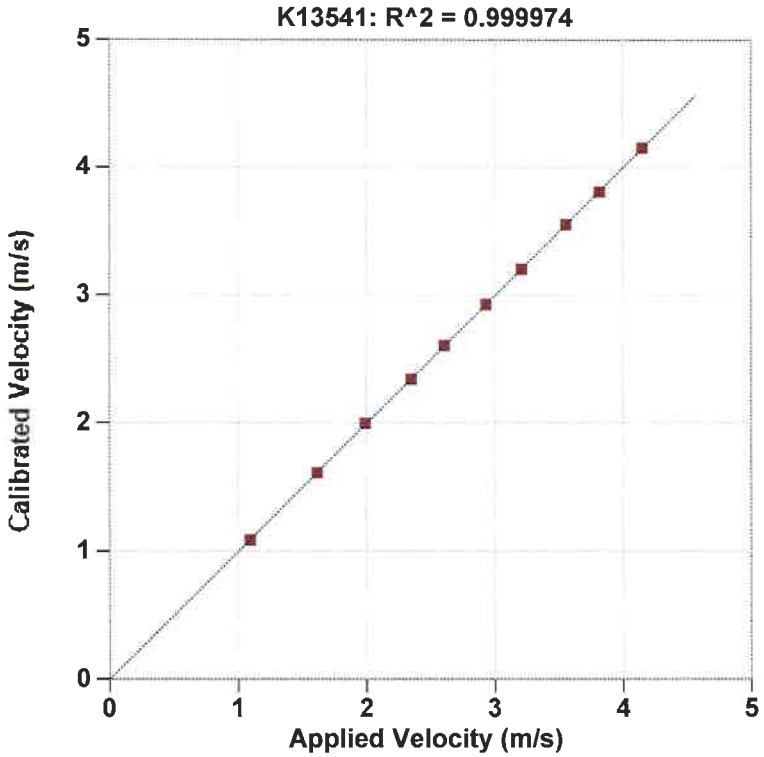
Reference accelerometer calibrations are traceable to the United States National Institute of Standards and Technology (NIST).

PDA CALIBRATION FACTOR

385.4 mv/5000g
(77.1 µv/g)
R^2: 0.999974 [Chip programmed]

Operator: William Johnson

Signed



Reference Velocity	S/N K13541 Velocity
m/s	m/s
1.093	1.087
1.613	1.612
1.989	1.998
2.347	2.345
2.605	2.609
2.931	2.932
3.209	3.207
3.555	3.555
3.818	3.809
4.151	4.157

Maximum Acceleration: 905 g's

Version: 2020.30.170 -0.15

Accelerometer Calibration Certificate
Pile Dynamics, Inc.

Calibrated by Pile Dynamics, Inc.
Calibration performed on 12Sep2023

Serial No:	K2161	**Temperature:**	23.8 °C
Model:	PR	**Humidity:**	56%
Calibrated on:	Channel 3 on 8G 5161 LE		

Ref Acc 1:	72505! 1035 g's/volt	**Cal on:**	24Mar2022
Ref Acc 2:	72517! 1049 g's/volt	**Cal on:**	24Mar2022

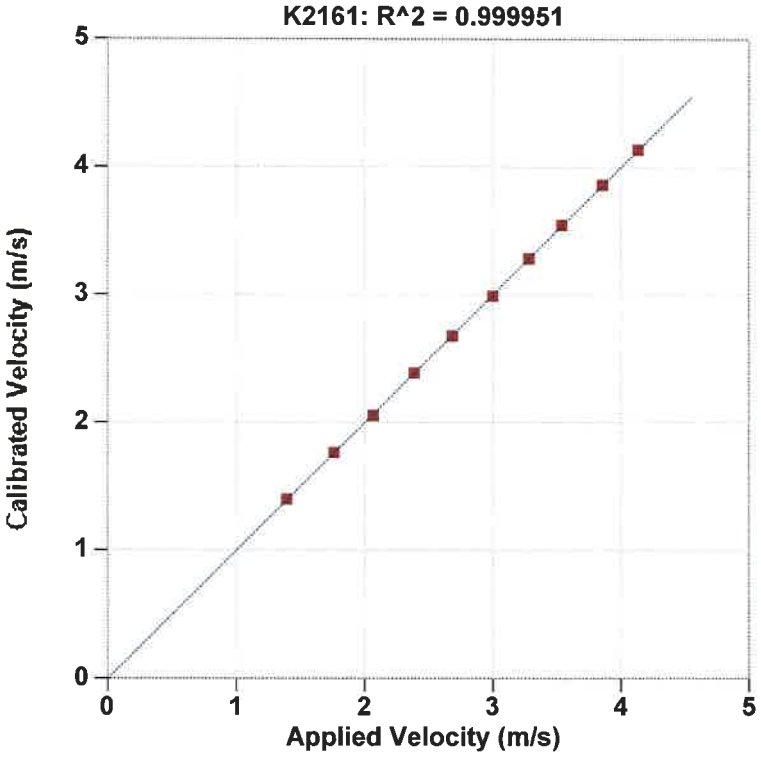
Reference accelerometer calibrations are traceable to the United States National Institute of Standards and Technology (NIST).

PDA CALIBRATION FACTOR

368.0 mv/5000g
(73.6 µv/g)
R^2: 0.999951 [Chip programmed]

Operator: William Johnson

Signed



Reference Velocity	S/N K2161 Velocity
m/s	m/s
1.394	1.402
1.762	1.765
2.069	2.059
2.388	2.390
2.684	2.681
3.001	2.989
3.283	3.282
3.540	3.543
3.857	3.861
4.133	4.138

Maximum Acceleration: 904 g's

Date printed: 12Sep2023, version: 2020.30.170 -0.82

Accelerometer Calibration Certificate
Pile Dynamics, Inc.

Calibrated by Pile Dynamics, Inc.
Calibration performed on OCT 0 9 2023

Serial No:	K13583	**Temperature:**	25.1 °C
Model:	PR	**Humidity:**	52%
Calibrated on:	Channel 3 on 8G 5161 LE		

Ref Acc 1:	72517! 1049 g's/volt	**Cal on:**	24Mar2022
Ref Acc 2:	72505! 1035 g's/volt	**Cal on:**	24Mar2022

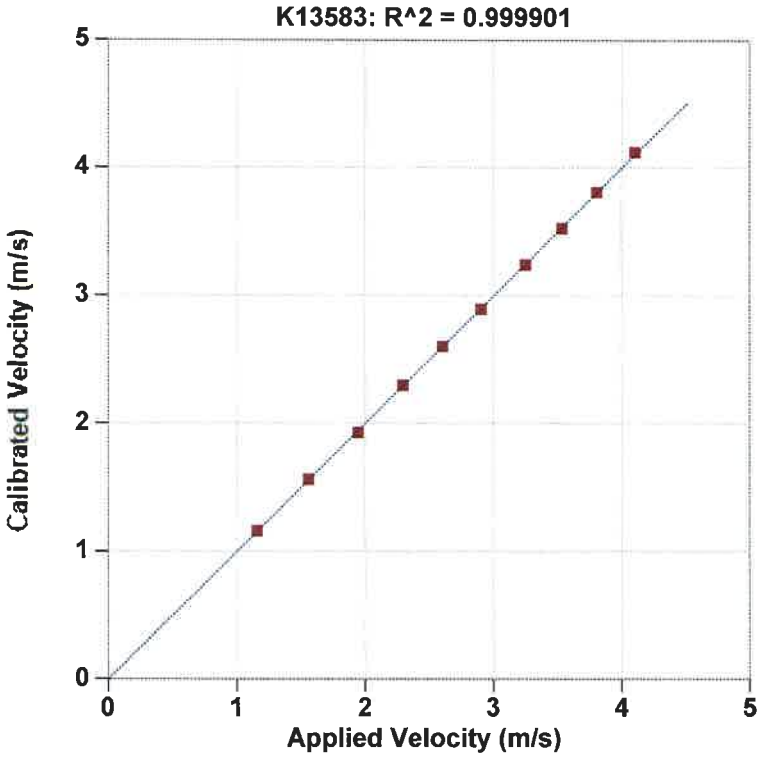
Reference accelerometer calibrations are traceable to the United States National Institute of Standards and Technology (NIST).

PDA CALIBRATION FACTOR

310.5 mv/5000g
(62.1 µv/g)
R^2: 0.999901 [Chip programmed]

Operator: William Johnson

Signed



Reference Velocity	S/N K13583 Velocity
m/s	m/s
1.158	1.161
1.560	1.564
1.946	1.930
2.295	2.298
2.602	2.604
2.902	2.895
3.252	3.243
3.535	3.526
3.805	3.809
4.103	4.121

Maximum Acceleration: 892 g's

Version: 2020.30.170 0.00