산림조합중앙회

구룡산 내곡동 321 예방사방사업 현장

동재하시험 보고서

§ 사방댐 (DUCTILE IRON PILE) §

2013. 4.

TAE AN Engineering & Construction Co., Ltd

태안특수건설(주)

품질시험 전문기관(제2008-14호)

엔지니어링활동주체신고(토질및기초,제10-1765호)

제 출 문

산림조합중앙회 귀중

귀 사에서 의뢰하신 " 구룡산 내곡동 321 예방사방사업 현장 "에 시공된 기초말뚝(디아이파일 : DUCTILE IRON PILE Φ118mmx9t)의 동재하시험을 수행하고 그 과업에 대한 결과를 분석 검토하고 보고서를 작성 제출합니다.

2013년 4월

■ 태 안 특 수 건 설(주)

품 질 검 사 전 문 기 관 제 **2008-14**호

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목 차

1. 서 론

1-1 시험목적

본 동재하시험은 산림조합중앙회에서 시공중인 구룡산 내곡동 321 예방사방사업 현장의 사방댐 기초에 시공된 Ductile iron pile(Φ118mm x 9t)에 시공된 기초말뚝에 대한 지지력을 말뚝항타분석기(Pile Driving Analyzer)을 이용하여 측정, 분석하여 설계 지지력과 허용지지력을 비교, 설계지지력의 타당성을 확인하는 것을 주목적으로 한다.

1-2 시험파일의 제원 및 시험위치

본 현장에 사용된 말뚝은 직경 Φ=118mm t=9mm의 Ductile iron pile로써 시험말뚝의 제원 및 시험위치는 다음과 같다.

표1. 시험말뚝의 제원

대상구조물	PILE NO	시험 조건	시공방법		시공일자	시험일자	파일지지력 (kn)
			항타장비	낙하고			
사방댐	43	Restrike	Drop 2.5 ton	1m	2013.4.5	2013.4.8	605
	44	Restrike	Drop 2.5 ton	1m	2013.4.5	2013.4.8	605

주1) Restrike (시공후 일정시간 경과후 실시)

1-3 시험결과의 해석방법

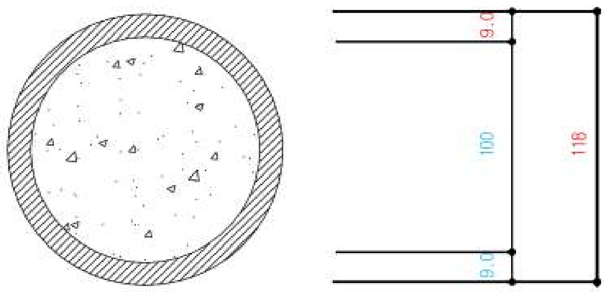
동재하시험을 할 때 현장에서는 PDA 를 통하여 해머 타격에 의해 말뚝에 발생하는 힘과 속도를 기록함과 동시에 PDA에 내장된 컴퓨터를 이용하여 CASE 방법으로 지지력을 계산한다. 동재하 시험에서 측정되는 근본적인 값은 타격에 의한 관입 저항력이다. 이 관입 저항력은 정적인 성분과 동적인 성분이 합쳐져 있다. 전체 저항력에서 동적인 성분이 얼마나 되는가는 지반의 특성에 따라 달라진다. 일반적으로 세립토가 조립토보다 동적 저항력이 크다. 전체 저항력에서 동적 저항력을 빼기 위하여 감쇄계수를 도입한다. CASE 방법에서는 감쇄계수를 가정하여 정적 지지력을 구하게 된다. CASE 방법은 감쇄계수를 가정하기 때문에 오류가 발생할 수 있을 뿐만 아니라 말뚝의 단면적이 일정하지 않을 경우에는 적용이 어렵다. 이러한 단점을 극복하기 위하여 CAPWAP (Case Pile Wave Analysis Program) 이라는 프로그램이 개발되었다. CAPWAP은 항타 과정을 모델링하고 모델의 경계조건(지지력 분포, 감쇄계수)을 변화시켜가며 시행착오법에 의해 실측된 힘과 속도를 모델에서 계산된 힘과 속도를 근접시키는 방법이다.

1-4 파일지지력 (참고자료 : Ductile Iron Pile 능력계산서, 현장도면)

■ NON GROUT 허용 하중 값 산정

2.3.1 규격 Ø118 X 9.0t

- 규격: Ø 118 × 9.0t
- Ø 118 × 9.0t 일때 허용 하중 값은 603.19 KN이다.



부식두께 1.5 mm 고려하여

- $A_s = \dfrac{\pi \times 11.5^2 cm}{4} - \dfrac{\pi \times 10^2 cm}{4} = 25.33\ cm^2$

$$허용하중\ KN = \frac{1}{r_b} \times A_b \times \beta_R + \frac{1}{r_s} \times A_s \times \delta_{SU} = 603.19\ KN$$

- β_R = Con'c 강도 X 저감계수
  = 24.0 N x 0.7 = 16.80 N/mm²
- r_b = 콘크리트 강도 안전계수 (DIN 1045) = 2.1
- r_S = CAST IRON의 강도 안전계수 (DIN 1045) = 1.5
- A_b = 콘크리트 단면적 = 78.54 cm²
- A_S = CAST IRON의 단면적 = 25.33 cm²
- δ_{SU} = CAST IRON의 강도 = 320.0 N/mm²

- $N = \dfrac{78.54\ cm^2 \times 16.80\ N/mm^2}{2.1} + \dfrac{25.33\ cm^2 \times 320.0\ N/mm^2}{1.5}$

$= 62.83\ KN + 540.35\ KN = 603.19\ KN \quad \therefore 603.19\ KN$

그림1. Ductile Pile 능력계산서 참조

표2. Ductile Iron Pile 지지력 산정(설계도면 참조)

Pile Type (외경) (mm)	두께 (mm)	주철단면적 (cm^2)	콘크리트 단 면 적 (cm^2)	주철지지력 (KN)	콘크리트 지 지 력 (KN)	파일지지력 (KN)
118	9.0	25.33	78.54	540	65	605

1-5 Ductile Iron Pile 지지력산정 (안전율)

동재하시험 결과로부터 허용하중을 결정하기 위해서는 항복하중을 적절한 안전율로 나누어 주어야 한다. 이때 하중 - 침하 거동을 잘 분석하여 사용하중 범위에서 과도한 침하가 일어나지 않도록 허용하중을 결정하여야 한다.

본 현장의 Ductile Iron Pile의 허용지지력은 다음과 같이 산정하였다.

1) CAPWAP 분석하여 지지력 산정하고,

2) CAPWAP 분석결과 산정된 지지력에 Ductile Iron Pile 능력계산서에 사용된 CAST IRON의 강도안전계수 (DIN 1045) 1.5 적용하여 파일지지력 산정.

2. 시험결과

2-1. 동재하시험 현장시험 결과

표3.현장시험결과

측 정 항 목		단위	현장시험결과 (CASE)	
			사방댐 PILE NO.43	사방댐 PILE NO.44
			Blows No.2	Blows No.2
1. 사용해머		ton	2.5 ton drop hammer	2.5 ton drop hammer
2. 낙하고		m	1.0	1.0
3. 항 타 에너지	EMX (측정 PDA)	KN-m	13.2	13.4
	ER (정격 WH)	KN-m	24.5	24.5
4. 햄머효율 ETR (EMX/ER)		%	54.0	54.5
5. 압축응력 (기준:센서)	두부응력 CSX	Mpa	276.8	279.7
	선단응력 CSB	Mpa	157.3	159.4
	인장응력 TSX	Mpa	18.6	19.8
6. 항타시 말뚝의 지지력 RMX		KN	795	798
7. 말뚝의 관입깊이		m	16.2 (현재 G.L 기준)	16.5 (현재 G.L 기준)

2-2. PDA 분석결과 (CAPWAP RESULTS)

표4. CAPWAP 분석결과

시험위치	Pile No	관입 심도 (M)	시험 구분	분석 방법	전 체 지지력 (KN)	주 면 마찰력 (KN)	선 단 지지력 (KN)
사방댐	43	16.2	RESTRIKE	CAPWAP	965.0	512.0	453.0
	44	16.5	RESTRIKE	CAPWAP	1025.0	495.4	529.6

※ 1 TON = 9.964 KN으로 단위환산함.

2-3. 허용지지력 평가 (DIN 1045 기준)

표5. 허용지지력 평가

시험위치	Pile No	관입 심도 (M)	시험 구분	전체지지력 (KN)	CAST IRON 강도안전계수 (DIN 1045)	허용지지력 (KN)	파 일 지지력 (KN)	판정
사방댐	43	16.2	RESTRIKE	965.0	1.5	643.3	540 (605)	O.K
	44	16.5	RESTRIKE	1025.0	1.5	683.3	540 (605)	O.K

※ 상기의 시험결과중 파일지지력은 Ductile Iron Pile의 내부에 콘크리트가 주입된 파일지지력임(605 KN).
※ 상기의 시험결과중 허용지지력은 Ductile Iron Pile의 내부에 콘크리트가 주입되기전의 시험결과임.

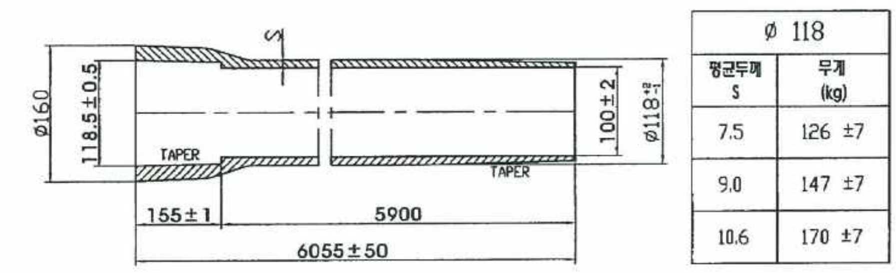
2-4. INPUT DATA 계산

본 시험말뚝은 Ductile Iron Pile(Φ118mm x 9t)이며, 시험시 입력 데이터는 다음과 같다.

표6. INPUT DATA (Pile Properties)

대 상 구조물	Pile No	LE (m)	LP (m)	AR (cm^2)	EM (t/cm^2)	SP (t/m^3)	WS (m/s)
사방댐	43	16.7	16.2	30.8	1606	7.05	4726.5
	44	16.7	16.5	30.8	1606	7.05	4726.5

그림2. 디아이파일 제원표



인장강도(Tensile strength)	min. 500 N/mm²	브리넬경도(Brinell - Hardness)	max. 230 HB
항복강도(0,2 % - yield strength)	min. 320 N/mm²	탄성계수(Young's Modulus)	160.000 N/mm²
연신율(elongation at rupture)	min. 10%	비중(Density)	7,05 g/cm³

덕타일주철기준 : KSD4311, ISO2531

파일본체(Pile tube) ø118 / 6,000

ø 118	
평균두께 S	무게 (kg)
7.5	126 ±7
9.0	147 ±7
10.6	170 ±7

3. 결론

3-1. 시험개요

본 현장은 구룡산 내곡동 321 예방사방사업 현장에 시공된 Ductile Iron Pile(Φ118mm x 9t)에 대한 지지력을 측정하기 위하여 PDA(동재하시험)를 실시하였다.

3-2. 시공개요

한길브레이커(동일기종:TB200G -타격파워 대략 25ton)를 사용하여 항타 관입.(그림3. 참조)

	
Rock Point Shoe 거치(시공위치)	수직도 Check
	
DX210W(08급) 브레이커로 항타관입	시공관리 (10회 타격후 5mm 관입) 1회/0.5mm관입

그림3. 현장시공사진

3-3. 결 론

1. 본 시험말뚝의 Ductile Iron Pile(Φ118mm x 9t)을 사용하여 굴삭기에 부착된 브레이커를 사용하여 관입시킨 말뚝이며, 시험은 말뚝설치후 3일이 경과한 시점에서 재항타 시험으로 실시하

였다. 시험시 낙하고는 말뚝에 작용하는 응력을 고려하며, 2.5 ton 드롭햄머로 1m로 낙추시켜 동재하시험을 실시하였다.

2. 시공말뚝의 허용지지력은 DIN 1045 기준에 의거 안전율1.5를 적용할 경우 허용지지력은 설계지지력을 만족 하는 것으로 확인 되었다.(표7. 참조)

표7. 시험결과 정리

시험위치	Pile No	관입 심도 (M)	시험 구분	전체지지력 (KN)	CAST IRON 강도안전계수 (DIN 1045)	허용지지력 (KN)	파 일 지지력 (KN)	판정
사방댐	43	16.2	RESTRIKE	965.0	1.5	643.3	605	O.K
	44	16.5	RESTRIKE	1025.0	1.5	683.3	605	O.K

부 록

부록 1. 설계도면

부록 2. 참고자료 (Ductile Iron Pile)

부록 3. CASE 및 CAPWAP 분석결과

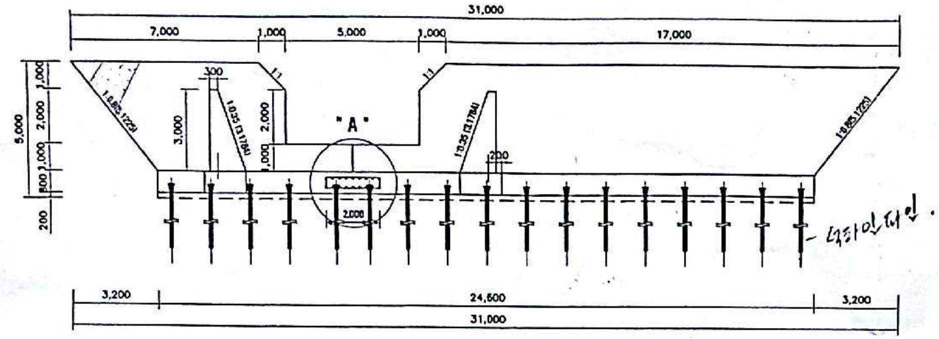
부록 4. 센서 검교정성적서 사본

부록 5. 현장시험 사진

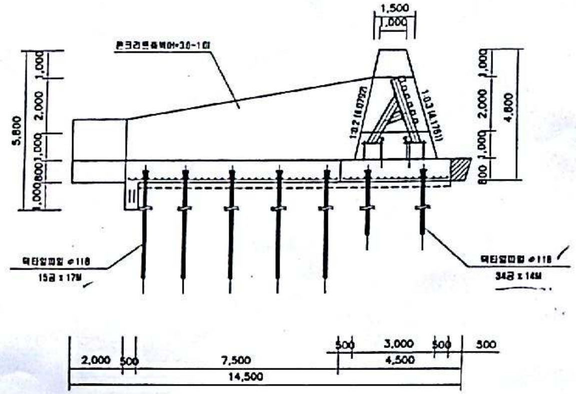
부록 6. 품질시험전문기관 등록증 사본

부 록. 1

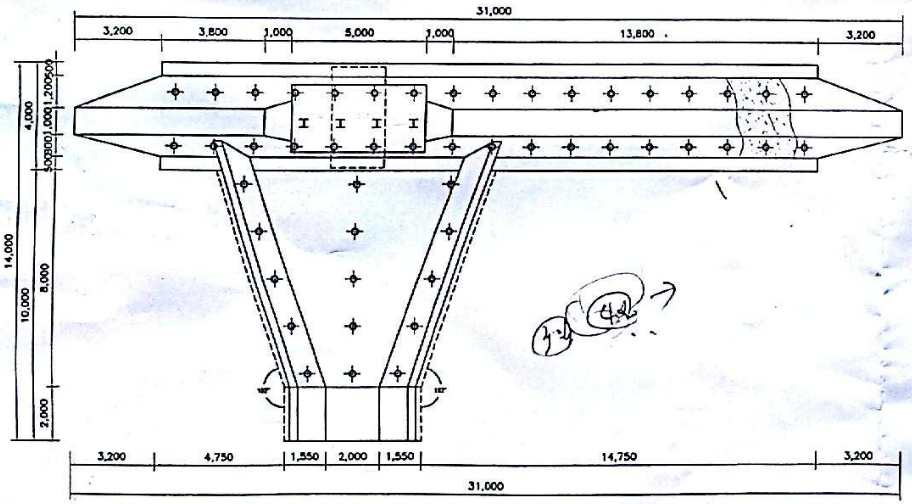
설 계 도 면



정 면 도

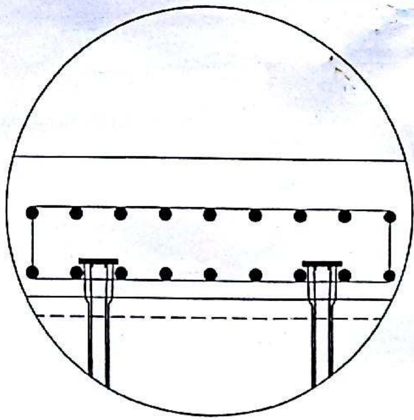


측 면 도



덕타일파일 배치도

기초내 두부설치
DETAIL "A"



⌖ 덕타일파일 ⌀118 - 49공

산림조합중앙회 엔지니어링사업본부 National Forestry Cooperative Federation Engineering Center	공사명 PROJECT TITLE	2012년 구룡산 내곡동 321 예방사방사업	설계 DESIGNED BY		심사 CHECKED BY	날짜 DATE: 2012. . .	도면구분 DRAWING NO.	NO.
	도면명 DRAWING TITLE	덕타일 배치도	제도 DRAWN BY		승인 APPROVED BY	축척 SCALE: A1 : 1 / 100, A3 : 1 / 200	도면번호 SHEET NO.	47

덕타일파일 상세도

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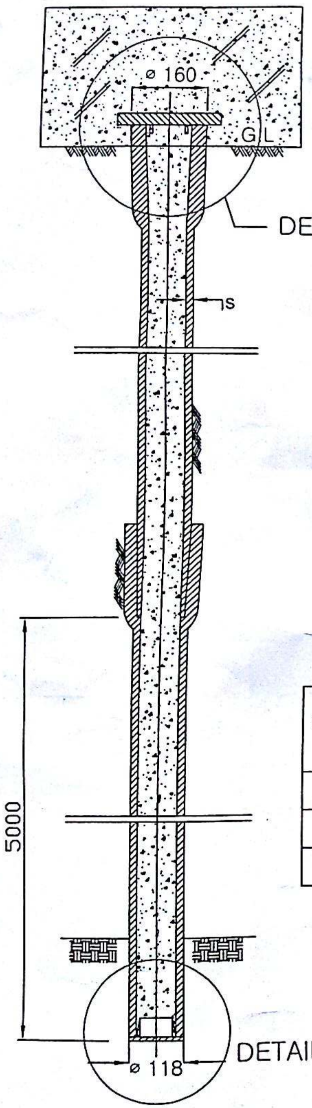
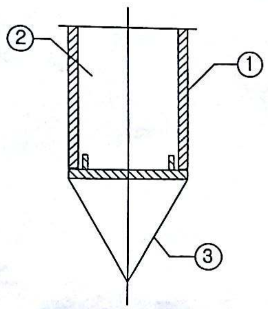
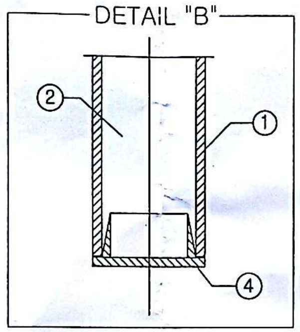


파일선단 A type



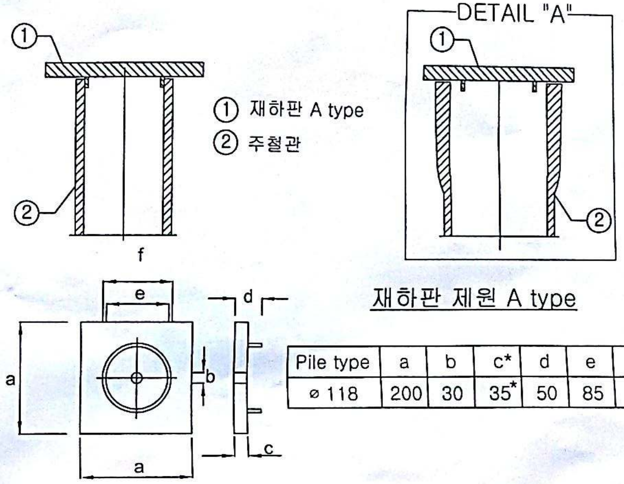
① 주철관
② 시멘트 그라우팅
③ 선단부

파일선단 B type



① 주철관
② 시멘트 그라우팅
④ 선단부

말뚝두부 A type



① 재하판 A type
② 주철관

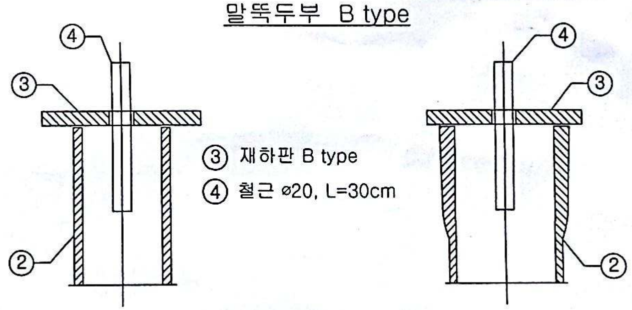
재하판 제원 A type

Pile type	a	b	c*	d	e	f
ø 118	200	30	35*	50	85	95

Pile type Øoutside	두께	주철단면적	콘크리트 단면적	주철지지력	콘크리트 지지력	파일지지력
(mm)	(mm)	(cm²)	(cm²)	(kN)	(kN)	(kN)
118	7.5	20.55	83.32	438	69	507
118	9.0	25.33	78.54	540	65	605

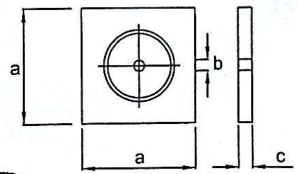
ø 118	
nom. S	Weight
7,5	105 kg ± 7kg
9,0	123 kg ± 7kg

말뚝두부 B type



③ 재하판 B type
④ 철근 ø20, L=30cm

재하판 제원 B type



Pile type	a	b	c*
ø 118	200	30	35*

산림조합중앙회 엔지니어링사업본부
National Forestry Cooperative Federation Engineering Center

공사명 PROJECT TITLE	2012년 구룡산 내곡동 321 예방사방사업	설계 DESIGNED BY	심사 CHECKED BY	날짜 DATE 2012. . .	도면구분 DRAWING NO.
도면명 DRAWING TITLE	덕타일 파일 상세도(118mm)	제도 DRAWN BY	승인 APPROVED BY	축척 SCALE A1 : 1 / NONE A3 : 1 / NONE	도면번호 SHEET NO.

NO.

48

부 록. 2

참고자료 (Ductile Iron Pile)

DYWIDAG-SYSTEMS INTERNATIONAL

DYWIDAG Driven Ductile Iron Pile

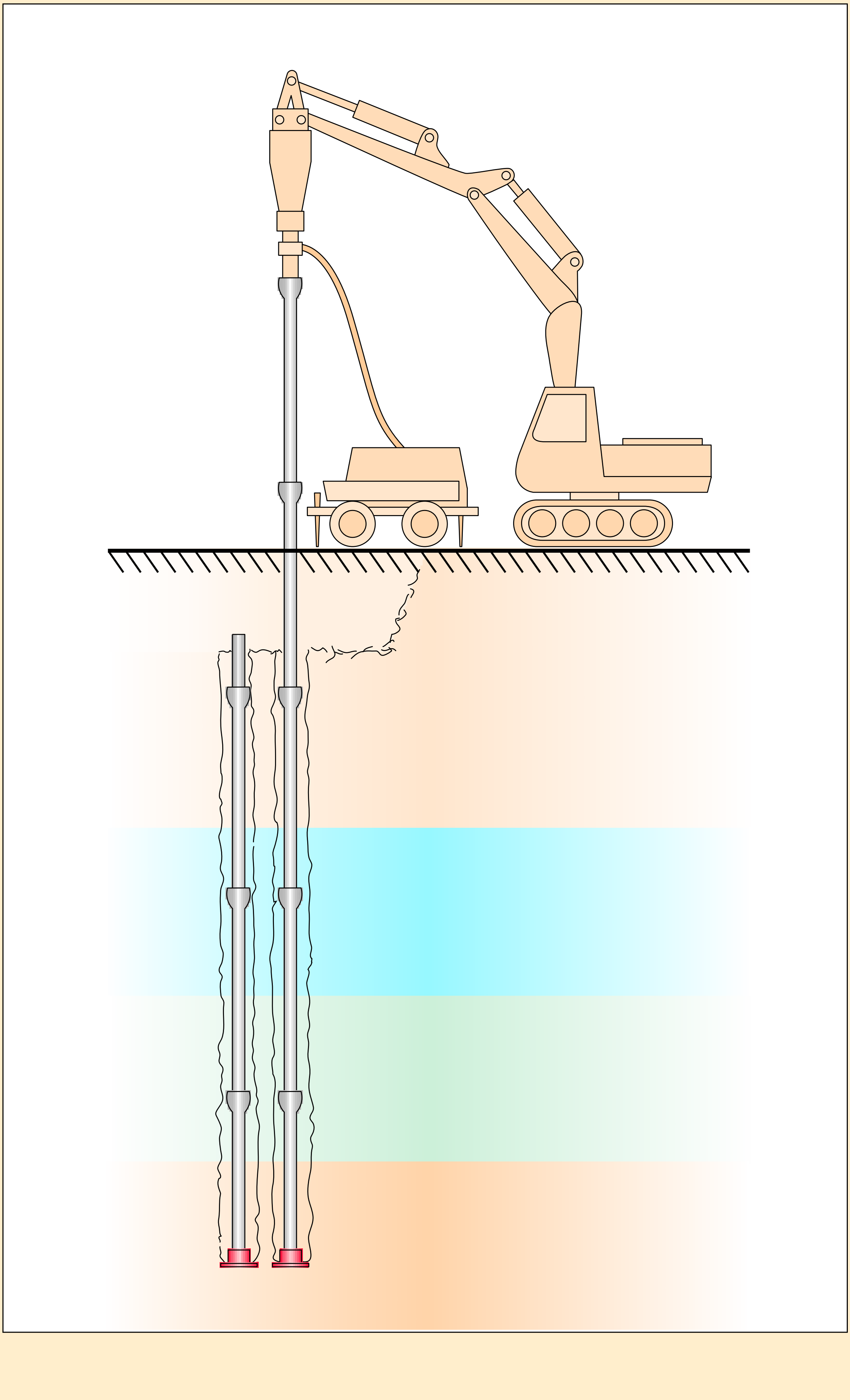
Installed by

Case Atlantic Company
14450 46th Street North
Suite 106
Clearwater, FL 33762

Tel 727 572-7740
Fax 727 571-1393
www.CaseAtlantic.com

CASE ATLANTIC
A Keller Company

KELLER



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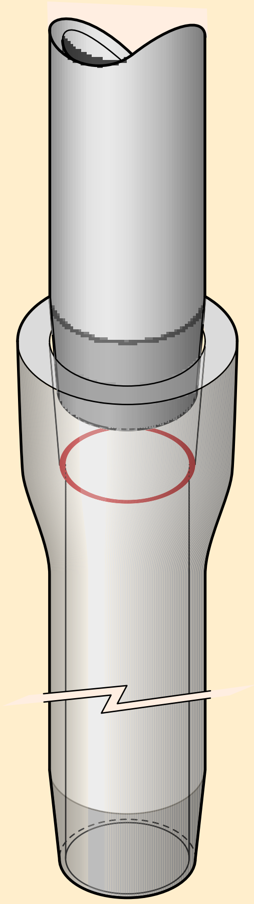


DYWIDAG Driven Ductile Iron Pile **page 4**

DYWIDAG Driven Ductile Iron Pile with grouted annulus **page 6**

DYWIDAG Driven Ductile Iron Piles

The DYWIDAG Driven Ductile Iron Pile is a driven pile system, utilizing high strength ductile cast iron. Pile sections are connected together by a unique spigot and socket joint, which offers speed of connection together with a high degree of stiffness. The piles are installed in a quick succession using an excavator with a hydraulic hammer, to both pitch and drive each pile section.

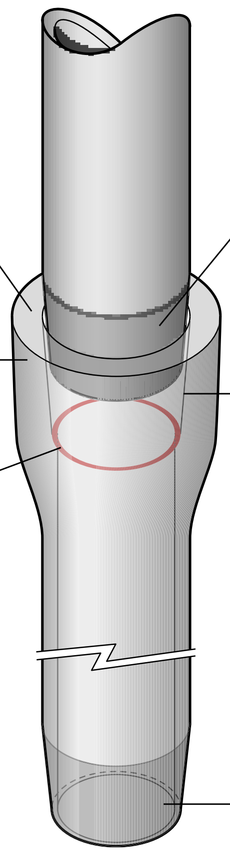
Manufactured as Ductile Cast Iron, also known as Speroidal Graphite Cast Iron, the system is immensely strong and offers superior durability over conventional tubular steel piles. Additional compressive strength is provided by the concreting or grouting of the bore, to form a composite pile.

Installed as an End-Bearing Pile (dry driven to a set, followed by concreting of the bore) or a Skin Friction Pile (simultaneous drive and grout, with an oversize shoe), the Ductile Iron Pile can accomondate a range of different ground conditions.

Advantages

- Spigot and socket joint for quick and easy connection of pile sections
- Very fast and almost vibration free pile production
- High production rates of up to 1,300 ft per day
- Control of load capacity through correlation with driving rate
- Can be used as a permanent pile
- Easy adaption of the pile length to different soil conditions
- No off-cuts or wastage
- Quick assembly of pile heads
- Light and versatile installation equipment allows pile productions under limited space conditions and in difficult terrain

Spigot and Socket Joint



Driving a ductile pile

The low mass of the individual pile sections means that piles can be driven with a light and versatile hydraulic excavator using a rapid-stroke hydraulic hammer. This permits pile foundations to be constructed where site conditions are difficult or space is limited.

With DYWIDAG Driven Ductile Iron Piles high bearing capacities can be obtained with a rapid-stroke hammer operated at very low impact energies.

This results in smoother operations and almost vibration-free pile-driving in the immediate vicinity of existing structures.

Pile placement is possible to within 13 in. of existing structures, and the use of excavators means that inclined piles can be placed at almost any rake.

Pile installation

The lead pile section is fitted with a pile shoe, and then pitched and driven. Additional pile sections are then added as required, to enable the pile to be driven to its full depth. The spigot and socket joint enables a very quick connection of the individual pile sections.

The pile is driven to the required depth as calculated from penetration resistance, and any excess length is simply cut off with a abrasive saw. The off-cut is then fitted with a new pile shoe and used as the first section of the next pile, resulting in no wastage. When pile driving is finished, the piles are filled with concrete to increase their bearing capacity and, depending on the loads required, the pile head is fitted with a pile cap or reinforcing cage.

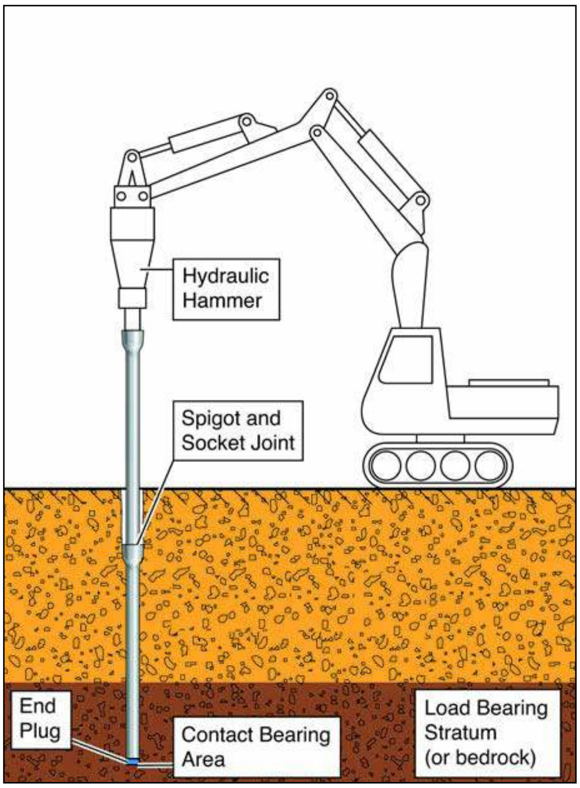
Driven Piles with Subsequent Placement of Concrete (typically end-bearing piles)

Installation of the Driven Ductile Iron Pile is one of the quickest and simplest piling methods available. The pile is driven to a "set" in dense gravel or on to bedrock. Concrete is then placed into the bore of the pile to give additional strength.

An end plug or rock point is fitted to the lead section, which is then driven to its full length, with additional sections added as required.

The set is defined as the reduced rate of pile penetration, in relation to a sustained driving energy (of the hammer), over a given time. Achievement of the set, demonstrates the pile's ability to sustain its design load on a long term basis.

The value for the set (i.e. penetration rate in relation to sustained driving energy) is determined from empirical data, correlated with static load test results, in a range of different ground conditions over many years.



▶ Set Data

Pile type	Hammer Size	Hammer Power	Penetration Rate
[mm] / [in]	Krupp / Atlas Copco	[Joules] / [ft-lbs]	[mm/min] / [in/min]
118 / 4.65	HM 1000 / MB 1700	3577 / 2638	30/1 / 1.2/1
170 / 6.69	HM 1500 / MB 2200	4950 / 3651	30/1 / 1.2/1

Notes:

1. Set should be proven by three re-drives on first five piles, thereafter once or twice, in conjunction with monitoring of adjacent driven pile lengths.
2. The more powerful hammers can be used with the smaller piles, but the rate of penetration for the set remains unchanged.

▶ Contact Bearing Area

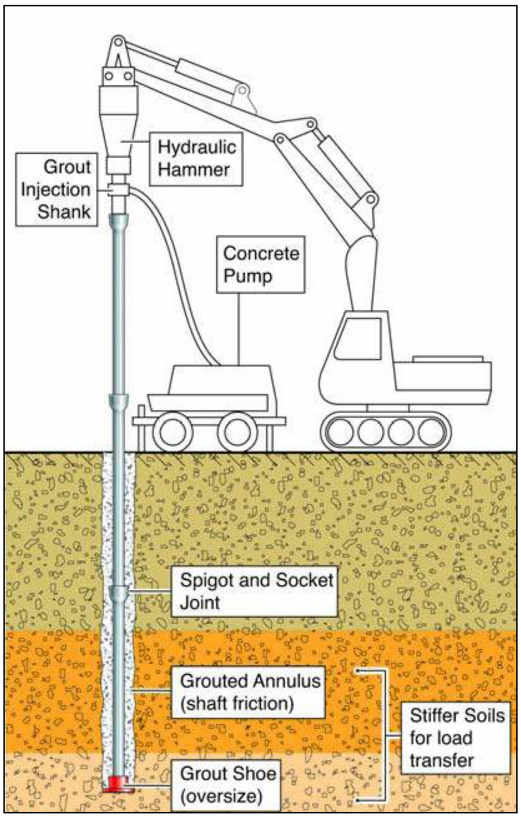
Pile type	End Plug	Contact Bearing Area of End Plug	Pile Socket	Extra Bearing Area of Socket
[mm] / [in]	[mm] / [in]	[mm^2] / [in^2]	[mm] / [in]	[mm^2] / [in^2]
118 / 4.56	120 / 4.72	11311 / 17.53	160 / 6.3	8797 / 13.64
170 / 6.69	175 / 6.89	24055 / 37.29	218 / 8.58	13275 / 20.58

▶ Concreting of the Pile Bore

For dry driven piles, the bore of the pile is concreted after driving, at the end of the shift (to limit standing time for concrete delivery trucks). The mix is discharged via a chute into the top of the pile.

A high slump cohesive mix (piling mix), with a 3/8" aggregate and high fines content is typically used to fill the bore of the pile. Slump of 6 to 7 in. collapse, ensures full placement in the bore. Concrete strength per project specifications.

Driven Piles with Grouted Annulus (typically skin friction piles)



Grouted driven piles combine the installation benefit of a driven pile with the flexibility of a grouted system.

An oversize grout shoe is fitted to the base of the lead pile section. As the pile is driven into the ground, the oversize shoe creates an annulus between the pile shaft and the ground, which is constantly filled with a pile-concrete, to mobilize skin friction.

Installed by the simultaneous drive and grout technique, grouted piles can be also used in ground conditions where other systems are not suitable (i.e. high ground water or contaminated sites).

▶ Indicative Driving Rates and Skin Friction Values

	Soil Type	[kPa] / [psi]	SPT [N] Value	Driving Rate [Sec/m] / [Sec/ft]	Skin Friction [N/mm²] / [psi]
Cohensive	Stiff	75-150 / 11-22	10-14	10-15 / 3-5	0.04 / 5.8
Cohensive	Very Stiff	150-300 / 22-44	16-30	15-30 / 5-9	0.07 / 10.15
Cohensive	Hard	> 300 / > 44	> 30	> 30 / > 9	0.1 / 14.5
Granular	Medium Dense		10-30	10-20 / 3-6	0.08 / 11.6
Granular	Dense		30-50	20-30 / 6-9	0.12 / 17.4
Granular	Very Dense		> 60	> 30 / > 9	0.15 / 21.75

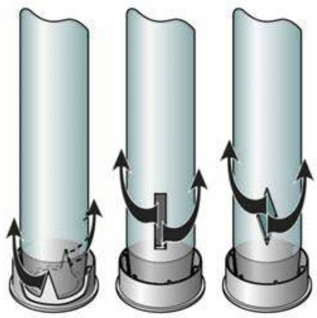
Notes:

1. Driving rates based on grout shoe (200mm dia. for 118mm piles, 250mm dia. for 170mm piles).
2. In cohesive soils, driving rates require careful assessment, due to the potential for build up of positive pore water pressures during driving.
3. Skin friction value of 0.04 N/mm2 (5.8 psi) is informative only, not used for pile loading.
4. Skin friction values are based on approximate stresses with a safety factor of 2 applied. Site trials should be conducted to establish actual values.

▶ Sanded Grout Mix

- Highly pumpable cohesive mix, to pass through 2 in. hoses and a 1-3/8" aperture in the hammer shank.
- Slump: 7 in. to collapse.
- Retarder: 6 hours (open life of mix is essential during pump downtime).

Grout Injection through the pile bore during driving



Cutaway Options for grout injection piles

Accessories

End plug
End plugs are the standard pile-caps for non-grouted piles.

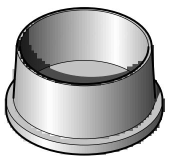
Rock Point
Rock points are an alternative to end plugs, if the non grouted piles are driven through a harder material, e.g. weathered rock

Grout shoe
Grout shoes are used if a grouted pile is installed. Grout shoes have a bigger diameter than the pile, creating an annulus around the pile, which enables the placement of fine-aggregate concrete over the full length of the pile shaft.

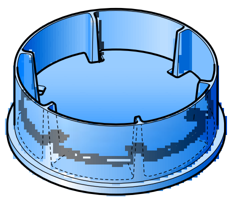
Coupler
Couplers can be used if two short pile sections must be connected in the place of the standard spigot and socket joint, e.g. if piles are driven in limited head room applications where the pile sections have to be cut.

Pipeline saddle
The pipeline saddle enables the DYWIDAG Ductile Iron Pile to be used as a support to pipelines in poor ground. The saddle provides uniform support for five pipe diameters from 7.8 to 19.6 in.

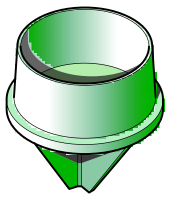
Bearing plate
The bearing plate is the standard fitting for compression piles. A center hole in the plate is required, to fix the plate horizontally with a dowel, to ensure correct allignment when casting the pile cap or beam.



End Plug
(end-bearing piles)

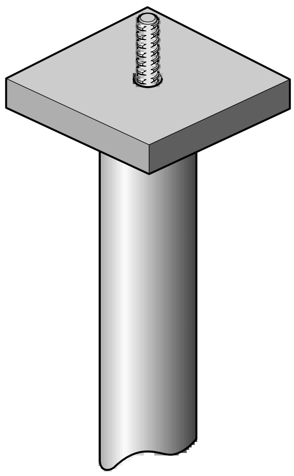


Grout Shoe c/w
Stiffening Plate
(skin friction piles)

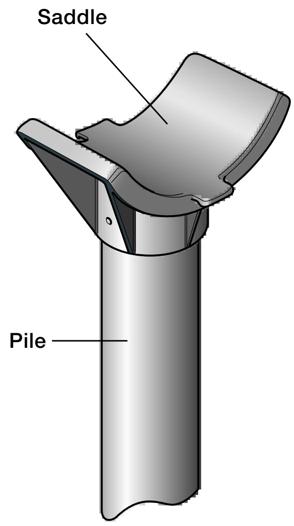


Rock Point
(end-bearing piles)

Coupler c/w
Centre Bridge



Bearing Plate for Pile Head
(centre hole for dowel connection)



Pipeline Saddle

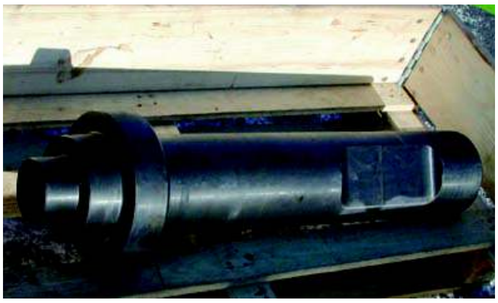
▶ **Dimensions**

Pile Type	End Plug (O.D.)	Grout Shoe (O.D.)	Rock Point (O.D.)	Bearing Plate	Coupler
[mm] / [in.]	[mm] / [in.]	[mm] / [in.]	[mm] / [in.]	[mm] / [in.]	[mm] / [in.]
118 / 4.65	120 / 4.72	200 / 7.87	120 / 4.72	200 x 200 41 / 7.87 x 7.87 x 1.625	165 dia. x 400 L / 6.5 dia. x 15.75
170 / 6.69	175 / 6.89	250 / 9.87	175 / 6.89	250 x 250 x 41 / 9.84 x 9.84 x 1.625	220 dia. x 450 L / 8.66 dia. 17.71 L

Notes:

1. End Plugs and Rock Points are specific to the wall thickness of each pile section.
2. Grout Shoes fit over the outside of the pile end. 200mm dia (7.787 in.) shoe fits both 118/7.5 and 118/9.0 pipes, 250mm dia. (9.84 in.) shoe fits both 170 pipes.
3. Coupler features a tapered internal bore at both ends, together with a center stop. Couplers are also used to connect field cut (off-cut) pipe sections or as a connection to the hammer shank. Note that the spigot ends of the pipe sections should be removed, to ensure full engagement against center stop.

Installation Plant and Equipment



Grout injection shank with grout box
Used for installation of grouted piles. Piling mix concrete (with a max. aggregate size of 4 mm) is pumped through the pile as it is driven, ensuring that the annulus between the pile shaft and the ground is fully grouted

Dry driving shank
Used for installation of end bearing piles. The dry driving shank is fitted into the excavator hammer, in place of the standard chisel. Piles are driven to a set and then filled with a concrete with 10 mm (3/8 in) aggregate.

▶ Excavation and Hammer Data

Pile type	Excavator Size	Hammer Type	Hammer Power	Hammer Blows	Hammer Length	Hammer Weight
[mm] / [in]	[tonnes] / [tons]	Krupp / Atlas Copco	[Joules] / [ft-lbs]	per minute	[m] / [ft]	[tonnes] / [tons]
118 / 4.56	25 / 28	HM 1000 / MB 1700	4020 / 2965	320-600	2.0 / 6.56	1.7 / 1.9
170 / 6.69	30 / 34	HM 1500 / MB 2200	4950 / 3651	280-550	2.2 / 7.22	2.2 / 2.46

Note:
Excavators must have sufficient boom / jib height, to handle the hammer length plus the pipe section. Minimum jib heights: 118 pile = 24 ft, 170 Piles = 24.61'.

Pile Testing

Static pile test

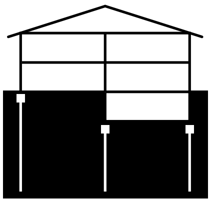
Both static and dynamic tests can be used to establish the ultimate bearing capacity of end-bearing and skin friction piles.

The static pilé test provides comprehensive data in respect of the pile's performance. Kentledge or anchor piles are required to provide a reaction, against which the pile can be loaded.

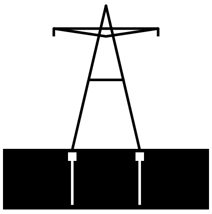
Dynamic pile testing enables the pile to be tested more quickly, using wave equation, but requires special considerations in respect of ductile piles (re. lateral support at the head of the pile and sufficient contact area for the hammer)

Applications

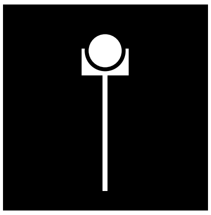
Housing apartments or factory units
With working loads between 112 kips and 290 kips, the DYWIDAG Ductile Iron Piles offer comparable loads to conventional mini piles.

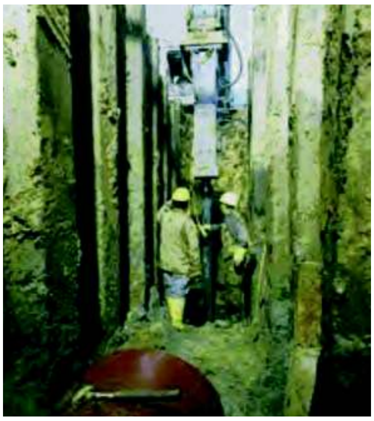


Pylons or Wind Turbines
Power transmission towers can be built on small foundations, which transfer the vertical loads into the ground via the DYWIDAG Ductile Iron Piles.

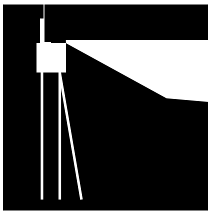


Pipeline support
Pipelines can be laid easily, precisely and free of settlements on special pipeline saddles, which can be mounted directly onto the DYWIDAG Ductile Iron Piles.



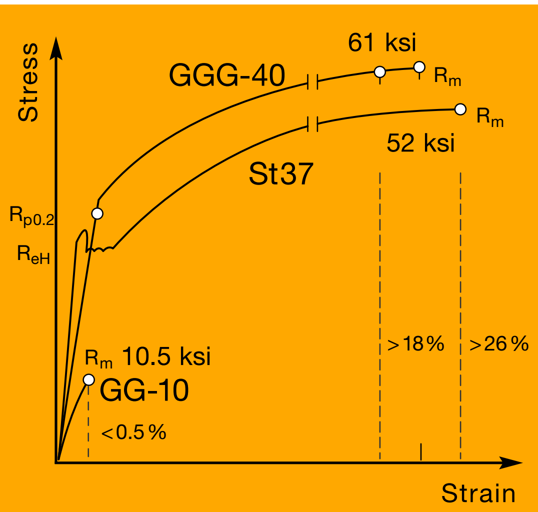


Infrastructure projects
DYWIDAG Ductile Iron Piles are used for the foundations and the strengthening of new or existing roads, railway lines and bridges.



Material

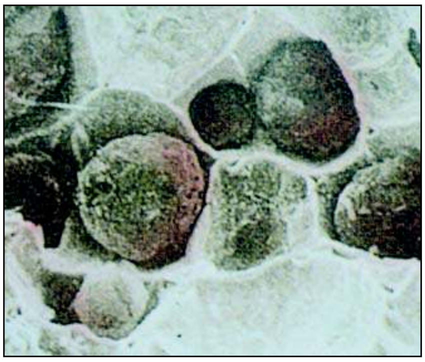
Ductile cast iron is a development of gray cast iron, a material which has been used for pipeline construction for centuries because of its high resistance against chemical and mechanical influences. Through its very high ductility, the ductile cast iron is capable of withstanding the high impact energies of the pile driving process.

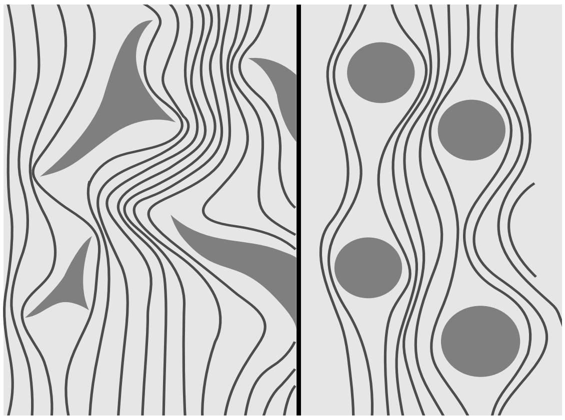


Stress strain diagram of the ductile iron used for the piles in comparison with gray cast iron and constructon steel (left), and magnified microstructure of the ductile cast iron with its typical speroidal graphite (right).

Relation of the Work Lines:

GG-ST37-GGG





Course of the Strain Lines:

Cast iron with lamellar graphite (gray cast iron = GG)
Cast iron with spheroidal graphite (ductile cast iron = GGG)
Construction steel (52 ksi = St 37)

Cast Iron with Spheroidal Graphite (GGG)
In the melted cast iron mass graphite is converted from a tapered lamellar (toothlike) shape (gray cast iron) into a spheroidal shape (ductile cast iron). Thus the mechanical characteristics are significantly changed, strength is increased and the material becomes more ductile.

▶ Specifications

Pipe Dia.	Pipe Thickness	Pipe Length	Weight per Pipe	Cross Section Area	Tensile Stress	Yield Stress	Ultimate Load	Yield Load	Section Modulas	Moment of Inertia
[mm] / [in.]	[mm] / [in.]	[m] / [ft]	[kg] / [lb]	$[mm^2]$ / $[in^2]$	[MPa] / [ksi]	[MPa] /[ksi]	[kN] / [kip]	[kN] / [kip]	$[cm^3]$ / $[in^3]$	$[cm^4]$ / $[in^4]$
118 / 4.56	7.5 / 0.30	5 / 16.4	105 / 231	2604 / 4.04	420 / 61	300 / 44	1093 / 246	781 / 176	68 / 4.15	399 / 9.59
118 / 4.65	9 / 0.35	5 / 16.4	123 / 271	3082 / 4.78	420 / 61	300 / 44	1294 / 291	925 / 208	78 / 4.76	461 / 11.08
118 / 4.65	10.6 / 0.42	5 / 16.4	142 / 313	3576 / 5.54	420 / 61	300 / 44	1502 / 338	1073 / 241	88 / 5.37	521 / 12.52
170 / 6.69	9 / 0.35	5 / 16.4	186 / 410	4552 / 7.06	420 / 61	300 / 44	1912 / 430	1366 / 307	174 / 10.62	1480 / 35.56
170 / 6.69	10.6 / 0.42	5 / 16.4	213 / 470	5308 / 8.23	420 / 61	300 / 44	2229 / 501	1592 / 358	199 / 12.14	1683 / 40.43

Notes:
1. Cross sectional areas are based on minimum values.
2. Section Lengths: 5.0m (16.4 ft) for all piles; Overall length of 118 pipe sections = 5.155m (16.914 ft), Overall length of 170 pipe sections = 5.215m (17.11 ft).
3. Working load of Ductile Iron calculated from yield stress x minimum cross sectional area, with standard code factors applied.
4. Modulas of Elasticity: E = 160,000 N/mm^2 (23,206 ksi)
5. Brinell Hardness: 230 HB max.
6. Density: 7.05 g/cm^3 (0.255 lb/in^3)

Corrosion Assessment for DYWIDAG Ductile Iron Piles

Non-grouted piles are exposed to the surrounding ground, thus certain corrosion rates for the piles have to be considered.

Most of the existing tables for corrosion of piles and/or sheet piles are set up for steel components. Cast iron behaves differently with respect to corrosion. First of all the corrosion speed of cast iron is generally lower and secondly the casting crust is an additional barrier which slows corrosion.

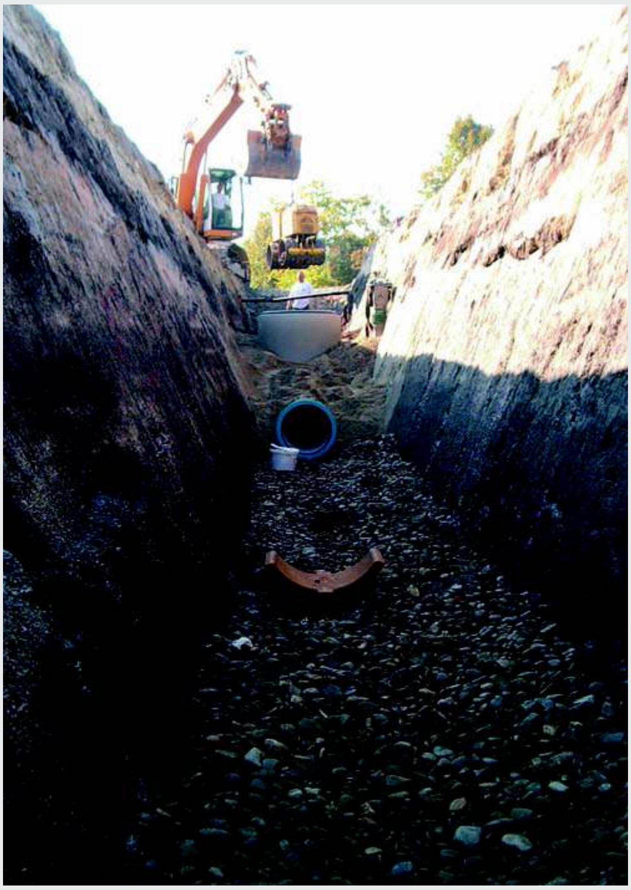
In Austria, where the Driven Ductile Iron Piles have been used for many years, sacrificial corrosion values are published in the standard ONR 22567 (as determined by MA39, i.e. Material Testing Authorities, Vienna).

Corrosion rates are dependant upon aggresivity levels of the ground and should be calculated on a site by site basis, to establish residual load bearing capacities. Additional corrosion protection measures include:

- stepping up to the thicker wall pile,
- use of the grout injection pile (external annulus of the pile is fully grouted)

References

Sewer Line on Piles, Erbach

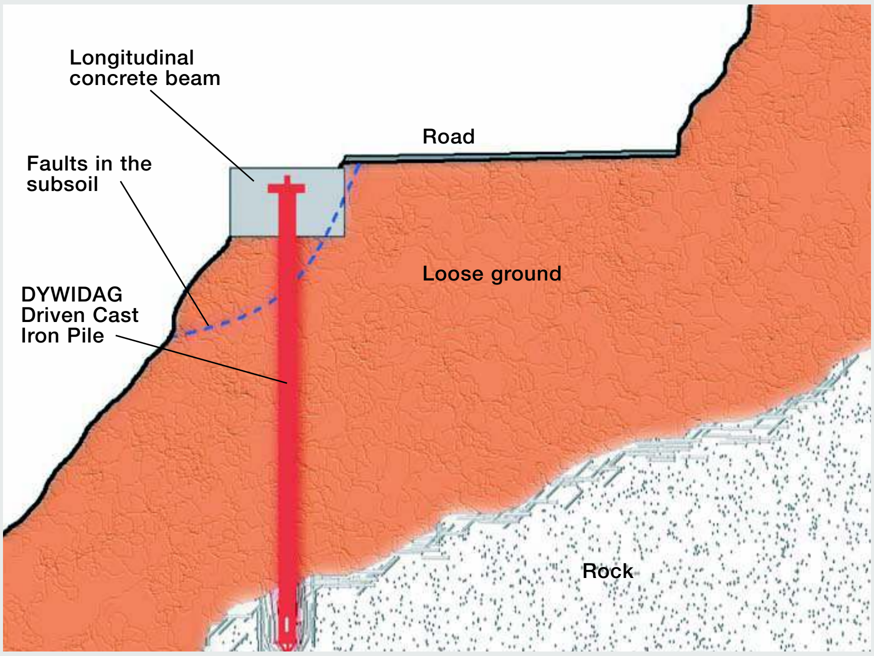


Client Motz Construction Co.
DSI Services Supply of 20 DYWIDAG Ductile Iron Piles, 200 lm, not-grouted, 20 pipe-saddles DN 400

References

First Use of DYWIDAG Ductile Iron Piles in France

Stabilization of a road connection in the Pyrenees



Owner Department Council of the High Pyrenees, France +++ **Contractor** Cabinet d'Etudes technique Jean Frugier, France +++ **Company** LTP, France

DSI Services Supply of DYWIDAG Ductile Iron Piles with an overall length of 160 m, ∅ 170 mm and accessories, technical assistance

Noerpel Forwarding Agency Warehouse, Ulm

Client Motz Construction Co.

DSI Services Supply of 865 DYWIDAG Ductile Iron Piles, 6.500 m, skin-grouted

References

Furnishing House Gamerdinger, Böblingen

Client Keller Grundbau
DSI Services Supply of 332 DYWIDAG Ductile Iron Piles, 3.500 m, not-grouted

Housing Apartments, Monaghan, Ireland

Client PJ Edwards
DSI Services Supply of 36 DYWIDAG Ductile Iron Piles, each 12-15 m long, non-grouted, technical support and site supervision

References

Coombedown, near Bath, UK

Client Ritchie Brothers Ltd., UK
DSI Services Supply of 118/7.5 DYWIDAG Ductile Iron Piles for crane bases

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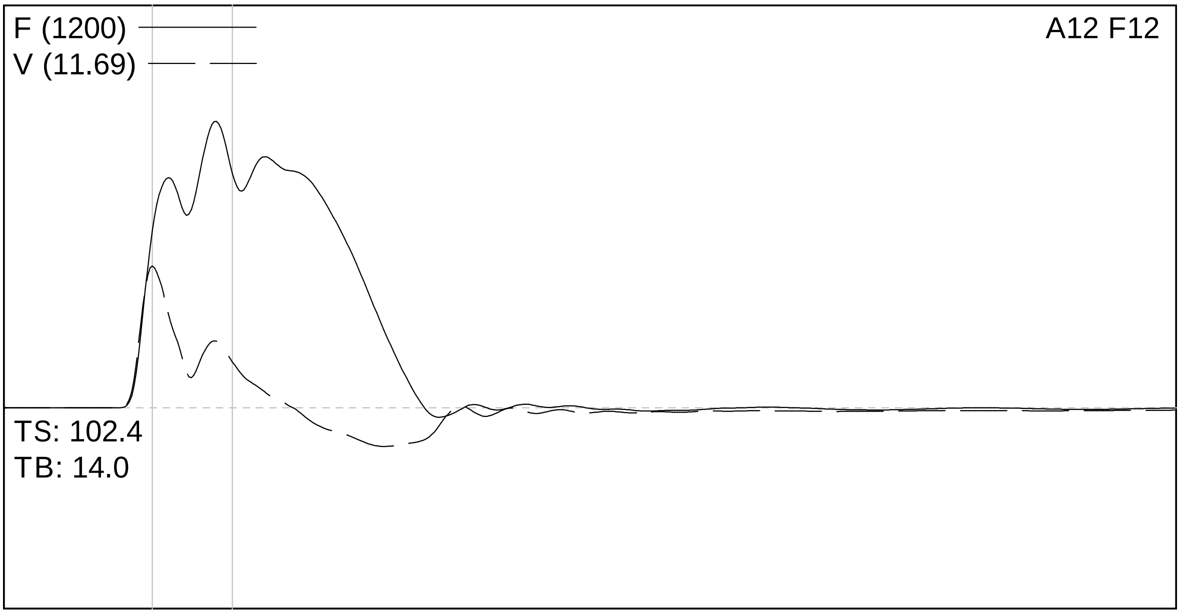
부 록. 3

CASE 및 CAPWAP 분석결과

NAEGOKDONG DI#43(R)



Project Information
PROJECT: NAEGOKDONG
PILE NAME: DI#43(R)
DESCR: DI
OPERATOR: OPERATOR
FILE: DI#43(R)
2013-04-08 오전 10:57:13
Blow Number 2

Pile Properties

LE	16.7	m
AR	30.82	cm^2
EM	157462	MPa
SP	69.1	kN/m3
WS	4726.0	m/s
EA/C	103	kN-s/m
2L/C	7.00	ms
JC	0.50	[]
LP	16.2	m

Quantity Results

CSX	276.8	MPa
CSB	157.3	MPa
TSX	18.6	MPa
EMX	13.2	kN-m
ETR	54.0	(%)
BTA	100.0	(%)
RMX	795	kN
RAU	691	kN
DFN	2	mm

Sensors
F1: [F228] 92.9 (1)
F2: [F230] 92.1 (1)
A1: [27024] 1120 g's/v (1)
A2: [27026] 1125 g's/v (1)
CLIP: OK

CAPWAP SUMMARY RESULTS

Total CAPWAP Capacity: 965.0; along Shaft 512.0; at Toe 453.0 kN

Soil Sgmnt No.	Dist. Below Gages	Depth Below Grade	Ru	Force in Pile	Sum of Ru	Unit Resist. (Depth)	Unit Resist. (Area)	Smith Damping Factor	Quake
	m	m	kN	kN	kN	kN/m	kPa	s/m	mm
				965.0					
1	2.1	1.6	31.2	933.8	31.2	19.65	52.97	1.313	1.524
2	4.2	3.7	33.9	899.9	65.1	16.24	43.77	1.313	1.521
3	6.3	5.8	37.5	862.4	102.6	17.96	47.14	1.313	1.521
4	8.3	7.8	47.9	814.5	150.5	22.95	61.85	1.313	1.521
5	10.4	9.9	73.0	741.5	223.5	34.97	97.67	1.313	1.521
6	12.5	12.0	104.9	636.6	328.4	50.25	132.92	1.313	1.521
7	14.6	14.1	108.7	527.9	437.1	52.07	140.36	1.313	1.341
8	16.7	16.2	74.9	453.0	512.0	35.88	96.71	1.313	0.910
Avg. Shaft			64.0			31.60	85.07	1.313	1.394
Toe			453.0				41422.82	0.252	1.595

Soil Model Parameters/Extensions		Shaft	Toe
Case Damping Factor		6.547	1.112
Unloading Quake	(% of loading quake)	37	36
Reloading Level	(% of Ru)	100	100
Resistance Gap (included in Toe Quake) (mm)			0.315
Soil Plug Weight	(kN)		0.57

CAPWAP match quality = 3.70 (Wave Up Match) ; RSA = 0
Observed: final set = 3.000 mm; blow count = 333 b/m
Computed: final set = 2.940 mm; blow count = 340 b/m

max. Top Comp. Stress = 277.2 MPa (T= 32.5 ms, max= 1.014 x Top)
max. Comp. Stress = 281.1 MPa (Z= 2.1 m, T= 32.7 ms)
max. Tens. Stress = -6.87 MPa (Z= 2.1 m, T= 73.8 ms)
max. Energy (EMX) = 11.98 kJ; max. Measured Top Displ. (DMX)=21.68 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	854.4	-20.4	277.2	-6.63	11.98	3.6	18.897
2	2.1	866.3	-21.2	281.1	-6.87	11.45	3.2	17.377
3	3.1	779.7	-0.2	253.0	-0.06	9.17	2.9	15.915
4	4.2	786.4	-0.2	255.1	-0.06	8.69	2.6	14.459
5	5.2	708.0	-0.1	134.6	-0.02	7.03	2.5	13.638
6	6.3	721.3	-0.1	234.0	-0.04	6.59	2.2	12.255
7	7.3	650.7	-0.1	211.1	-0.03	5.09	1.8	10.935
8	8.3	661.2	-0.1	214.5	-0.03	4.69	1.5	9.622
9	9.4	583.3	-0.1	189.3	-0.02	3.49	1.3	8.387
10	10.4	590.0	-0.1	188.8	-0.02	3.15	1.0	7.159
11	11.5	519.8	-0.0	112.6	-0.01	2.23	0.9	6.496
12	12.5	521.2	-0.0	169.1	-0.01	1.95	0.7	5.380
13	13.6	477.0	-0.0	154.8	-0.01	1.19	0.6	4.337
14	14.6	477.7	-0.0	155.0	-0.01	0.94	0.5	3.295
15	15.7	442.0	-0.0	143.4	-0.00	0.50	0.8	2.325
16	16.7	442.5	-0.0	143.6	-0.00	1.47	1.0	1.500
Absolute	2.1			281.1			(T =	32.7 ms)
	2.1				-6.87		(T =	73.8 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	754.6	735.2	715.7	696.3	676.9	657.4	638.0	618.6	599.2	579.7
RX	880.1	863.0	845.9	828.8	811.7	794.6	777.5	761.1	744.8	729.2
RU	754.6	735.2	715.7	696.3	676.9	657.4	638.0	618.6	599.2	579.7

RAU = 690.9 (kN); RA2 = 779.3 (kN)

Current CAPWAP Ru = 965.0 (kN); Corresponding J(RP)= 0.00; J(RX) = 0.00

VMX m/s	TVP ms	VT1*Z kN	FT1 kN	FMX kN	DMX mm	DFN mm	SET mm	EMX kJ	QUS kN
4.11	26.72	422.0	526.8	853.1	21.678	1.875	3.000	13.2	1073.1

PILE PROFILE AND PILE MODEL

Depth m	Area cm^2	E-Modulus MPa	Spec. Weight kN/m^3	Perim. m
0.00	30.82	157462.3	69.137	0.371
4.84	30.82	157462.3	69.137	0.371
4.84	173.00	157462.3	69.137	0.502
5.00	173.00	157462.3	69.137	0.502
5.00	30.82	157462.3	69.137	0.371
10.39	30.82	157462.3	69.137	0.371
10.39	173.00	157462.3	69.137	0.502
10.55	173.00	157462.3	69.137	0.502

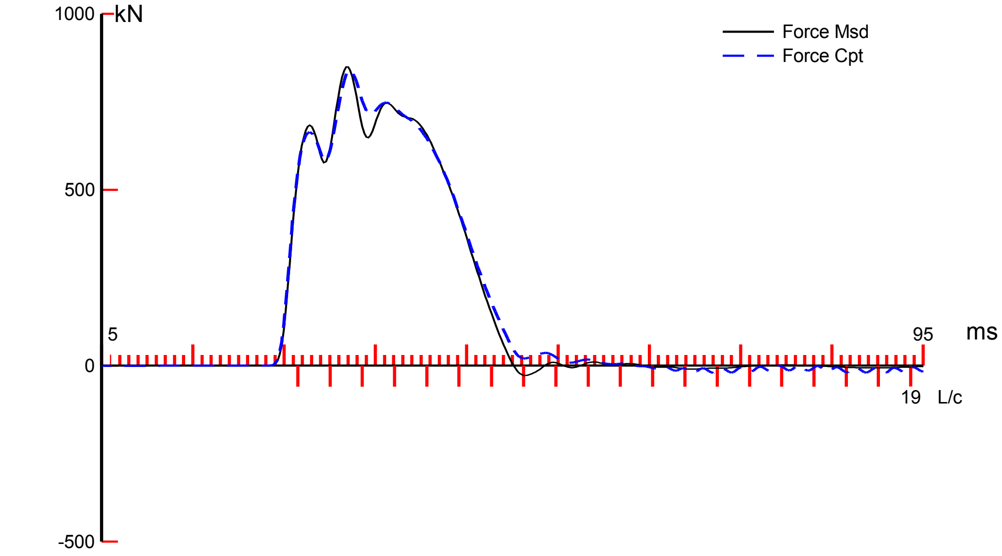
PILE PROFILE AND PILE MODEL

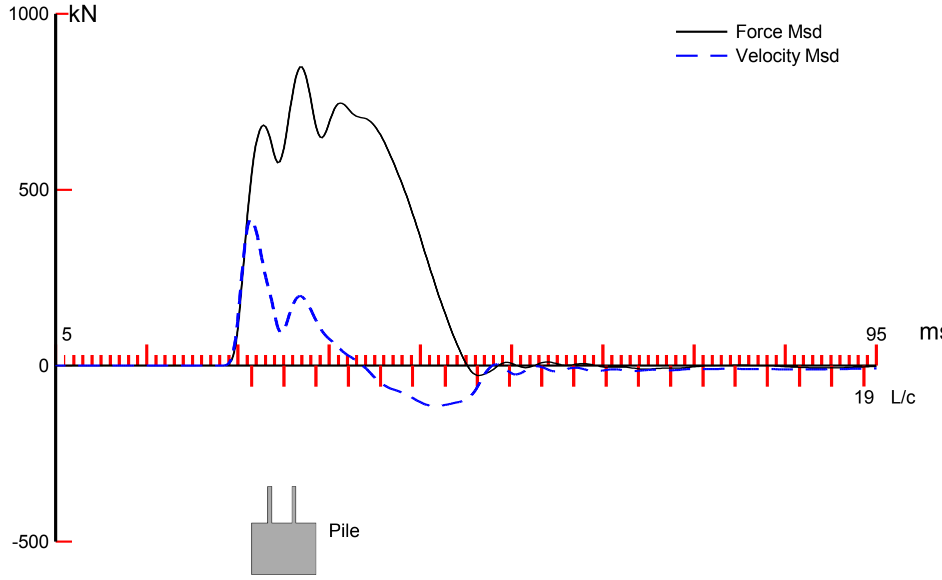
Depth	Area	E-Modulus	Spec. Weight	Perim.
m	cm^2	MPa	kN/m^3	m
10.55	30.82	157462.3	69.137	0.371
16.70	30.82	157462.3	69.137	0.371

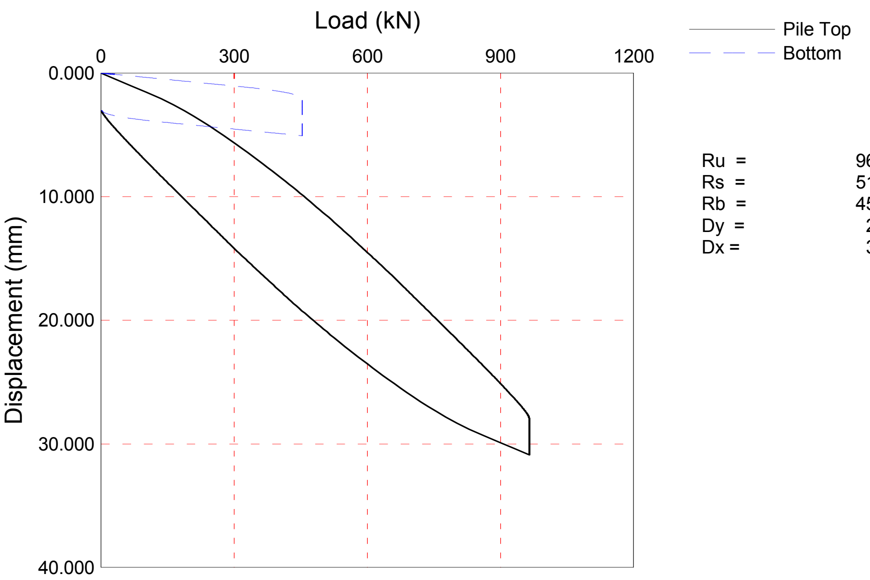
Toe Area 0.011 m^2

Segmnt Number	Dist. B.G.	Impedance	Imped. Change	Tension Slack	Tension Eff.	Compression Slack	Compression Eff.	Perim.
	m	kN/m/s	%	mm		mm		m
1	1.04	102.70	0.00	0.000	1.000	-0.000	0.000	0.371
2	2.09	102.70	0.00	0.000	0.000	-0.000	0.000	0.371
5	5.22	175.30	0.00	0.000	0.000	-0.000	0.000	0.391
6	6.26	102.70	0.00	0.000	0.000	-0.000	0.000	0.371
11	11.48	175.30	14.05	0.000	0.000	-0.000	0.000	0.385
12	12.52	102.70	0.00	0.000	0.000	-0.000	0.000	0.371
16	16.70	102.70	0.00	0.000	0.000	-0.000	0.000	0.371

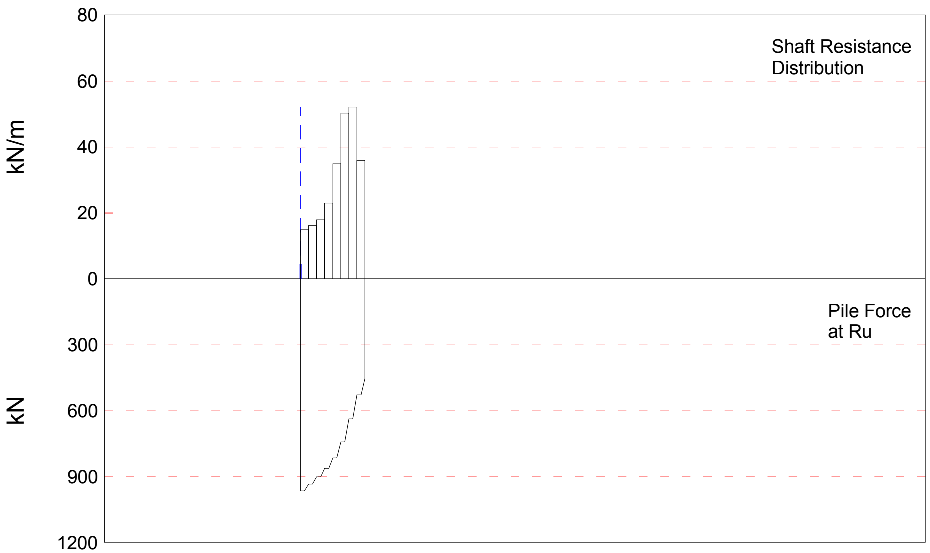
Pile Damping 2.0 %, Time Incr 0.221 ms, Wave Speed 4726.0 m/s, 2L/c 7.1 ms







Ru =	965.0	kN
Rs =	512.0	kN
Rb =	453.0	kN
Dy =	27.9	mm
Dx =	30.9	mm



STATIC ANALYSIS

Monotonic D-Toe, E-P R-Toe

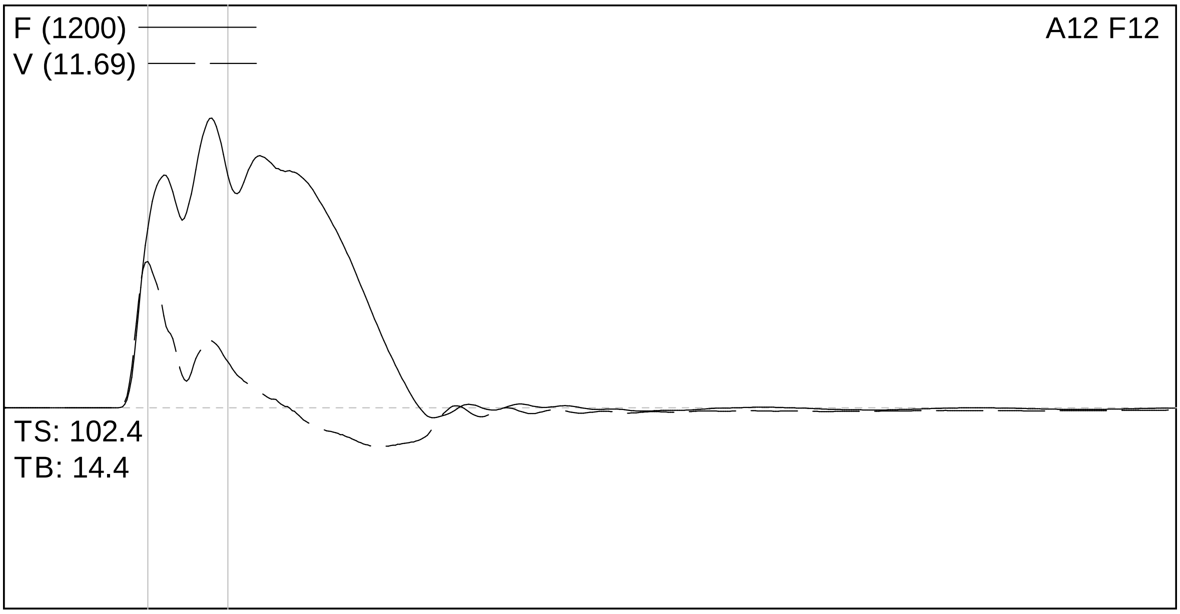
Step No.	Top Load kN	Top Disp. mm	Toe Load kN	Toe Disp. mm
0	0.0	0.000	0.0	0.000
1	34.0	0.521	2.6	0.009
2	68.1	1.042	5.1	0.018
3	102.1	1.563	7.7	0.027
4	135.7	2.082	10.3	0.036
5	163.1	2.574	12.9	0.045
6	187.9	3.049	15.4	0.054
8	227.8	3.908	20.6	0.072
10	261.0	4.688	25.7	0.090
12	290.8	5.419	30.8	0.109
14	318.3	6.114	36.0	0.127
17	353.4	7.052	43.7	0.154
20	385.8	7.935	51.4	0.181
23	415.5	8.763	59.1	0.208
26	440.4	9.492	66.8	0.235
30	471.1	10.408	77.1	0.271
34	499.4	11.264	87.4	0.308
38	525.1	12.060	97.7	0.344
43	552.1	12.929	110.5	0.389
48	576.8	13.742	123.4	0.434
53	600.1	14.515	136.2	0.480
59	626.4	15.393	151.6	0.534
65	650.6	16.215	167.1	0.588
72	675.8	17.085	185.1	0.652
79	698.5	17.886	203.1	0.715
86	720.6	18.666	221.0	0.778
94	745.1	19.534	241.6	0.851
102	768.9	20.377	262.2	0.923
110	791.8	21.194	282.7	0.995
118	814.0	21.985	303.3	1.068
127	837.8	22.839	326.2	1.149
136	859.5	23.623	347.5	1.231
146	880.8	24.405	368.8	1.321
158	903.1	25.238	391.1	1.430
171	923.4	26.013	411.4	1.548
188	943.7	26.825	431.7	1.701
213	960.8	27.605	448.8	1.928
230	965.0	27.896	453.0	2.081
316	965.0	28.675	453.0	2.860
402	965.0	29.453	453.0	3.638
488	965.0	30.231	453.0	4.416
564	931.0	30.371	450.4	5.068
565	896.9	29.850	447.9	5.059
566	862.9	29.329	445.3	5.050
567	829.3	28.810	442.7	5.041

STATIC ANALYSIS

Monotonic D-Toe, E-P R-Toe

Step No.	Top Load kN	Top Disp. mm	Toe Load kN	Toe Disp. mm
568	801.9	28.318	440.1	5.032
569	777.1	27.843	437.6	5.023
571	737.2	26.984	432.4	5.005
573	704.0	26.204	427.3	4.986
575	674.2	25.473	422.2	4.968
577	646.7	24.778	417.0	4.950
580	611.6	23.840	409.3	4.923
583	579.2	22.957	401.6	4.896
586	549.5	22.129	393.9	4.869
589	524.6	21.400	386.2	4.842
593	493.9	20.484	375.9	4.805
597	465.6	19.628	365.6	4.769
601	439.9	18.832	355.3	4.733
606	412.9	17.962	342.5	4.688
611	388.2	17.150	329.6	4.643
616	364.9	16.377	316.8	4.597
622	338.6	15.499	301.4	4.543
628	314.4	14.677	285.9	4.489
635	289.2	13.807	267.9	4.425
642	266.5	13.006	249.9	4.362
649	244.4	12.226	232.0	4.299
657	219.9	11.357	211.4	4.226
665	196.1	10.515	190.8	4.154
673	173.2	9.698	170.3	4.081
681	151.0	8.907	149.7	4.009
690	127.2	8.053	126.8	3.928
699	105.5	7.269	105.5	3.846
709	84.2	6.487	84.2	3.756
721	61.9	5.654	61.9	3.647
734	41.6	4.879	41.6	3.529
751	21.3	4.067	21.3	3.376
776	4.2	3.287	4.2	3.149

NAEGOKDONG DI#44(R)



Project Information

PROJECT: NAEGOKDONG
PILE NAME: DI#44(R)
DESCR: DI
OPERATOR: OPERATOR
FILE: DI#43(R)_2
2013-04-08 오전 11:58:13
Blow Number 2

Pile Properties

LE	16.7	m
AR	30.82	cm^2
EM	157462	MPa
SP	69.1	kN/m3
WS	4726.0	m/s
EA/C	103	kN-s/m
2L/C	7.00	ms
JC	0.50	[]
LP	16.5	m

Quantity Results

CSX	279.7	MPa
CSB	159.4	MPa
TSX	19.8	MPa
EMX	13.4	kN-m
ETR	54.5	(%)
BTA	100.0	(%)
RMX	798	kN
RAU	695	kN
DFN	2	mm

Sensors

F1: [F228] 92.9 (1)
F2: [F230] 92.1 (1)
A1: [27024] 1120 g's/v (1)
A2: [27026] 1125 g's/v (1)
CLIP: OK

CAPWAP SUMMARY RESULTS

Total CAPWAP Capacity: 1025.0; along Shaft 495.4; at Toe 529.6 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	Smith Damping Factor s/m	Quake mm
				1025.0					
1	2.1	1.9	37.7	987.3	37.7	19.97	53.84	1.302	1.369
2	4.2	4.0	41.0	946.3	78.7	19.64	52.94	1.302	1.365
3	6.3	6.1	45.4	900.9	124.1	21.75	57.08	1.302	1.365
4	8.3	8.2	57.9	843.0	182.0	27.74	74.76	1.302	1.365
5	10.4	10.2	88.3	754.7	270.3	42.30	118.14	1.302	1.365
6	12.5	12.3	45.0	709.7	315.3	21.56	57.02	1.302	1.365
7	14.6	14.4	89.5	620.2	404.8	42.87	115.56	1.302	1.203
8	16.7	16.5	90.6	529.6	495.4	43.40	116.98	1.302	0.817
Avg. Shaft			61.9			30.02	80.81	1.302	1.236
Toe			529.6				48427.21	0.264	1.580

Soil Model Parameters/Extensions		Shaft	Toe
Case Damping Factor		6.281	1.362
Unloading Quake	(% of loading quake)	42	43
Reloading Level	(% of Ru)	100	100
Resistance Gap (included in Toe Quake) (mm)			0.315
Soil Plug Weight	(kN)		0.58

CAPWAP match quality = 3.49 (Wave Up Match) ; RSA = 0
Observed: final set = 3.000 mm; blow count = 333 b/m
Computed: final set = 2.732 mm; blow count = 366 b/m

max. Top Comp. Stress = 280.5 MPa (T= 32.5 ms, max= 1.014 x Top)
max. Comp. Stress = 284.5 MPa (Z= 2.1 m, T= 32.7 ms)
max. Tens. Stress = -7.32 MPa (Z= 2.1 m, T= 91.7 ms)
max. Energy (EMX) = 11.77 kJ; max. Measured Top Displ. (DMX)=21.69 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	864.6	-22.4	280.5	-7.28	11.77	3.5	18.136
2	2.1	876.7	-22.5	284.5	-7.32	11.25	3.1	16.624
3	3.1	774.3	-0.2	251.2	-0.06	8.79	2.8	15.179
4	4.2	782.0	-0.2	253.7	-0.06	8.32	2.5	13.743
5	5.2	692.4	-0.1	131.6	-0.02	6.56	2.3	12.942
6	6.3	705.7	-0.1	229.0	-0.04	6.14	2.0	11.593
7	7.3	623.9	-0.1	202.4	-0.02	4.61	1.6	10.315
8	8.3	633.1	-0.1	205.4	-0.02	4.24	1.4	9.042
9	9.4	553.8	-0.0	179.7	-0.02	3.03	1.1	7.852
10	10.4	555.6	-0.0	177.8	-0.02	2.71	0.9	6.664
11	11.5	491.8	-0.0	106.6	-0.01	1.79	0.8	6.031
12	12.5	492.9	-0.0	159.9	-0.01	1.52	0.7	4.959
13	13.6	459.8	-0.0	149.2	-0.01	1.02	0.6	3.952
14	14.6	460.4	-0.0	149.4	-0.01	0.79	0.7	2.946
15	15.7	420.4	-0.0	136.4	-0.00	0.41	0.9	2.024
16	16.7	420.6	-0.0	136.5	-0.00	1.29	1.1	1.246
Absolute	2.1			284.5			(T =	32.7 ms)
	2.1				-7.32		(T =	91.7 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	761.7	740.9	720.1	699.4	678.6	657.9	637.1	616.3	595.6	574.8
RX	886.2	868.3	850.7	833.2	815.7	798.1	780.6	763.1	746.1	730.5
RU	761.7	740.9	720.1	699.4	678.6	657.9	637.1	616.3	595.6	574.8

RAU = 694.7 (kN); RA2 = 780.2 (kN)

Current CAPWAP Ru = 1025.0 (kN); Corresponding J(RP)= 0.00; J(RX) = 0.00

VMX m/s	TVP ms	VT1*Z kN	FT1 kN	FMX kN	DMX mm	DFN mm	SET mm	EMX kJ	QUS kN
4.24	26.50	435.8	533.5	861.9	21.687	1.875	3.000	13.4	1082.2

PILE PROFILE AND PILE MODEL

Depth m	Area cm^2	E-Modulus MPa	Spec. Weight kN/m^3	Perim. m
0.00	30.82	157462.3	69.137	0.371
4.84	30.82	157462.3	69.137	0.371
4.84	173.00	157462.3	69.137	0.502
5.00	173.00	157462.3	69.137	0.502
5.00	30.82	157462.3	69.137	0.371
10.39	30.82	157462.3	69.137	0.371
10.39	173.00	157462.3	69.137	0.502
10.55	173.00	157462.3	69.137	0.502

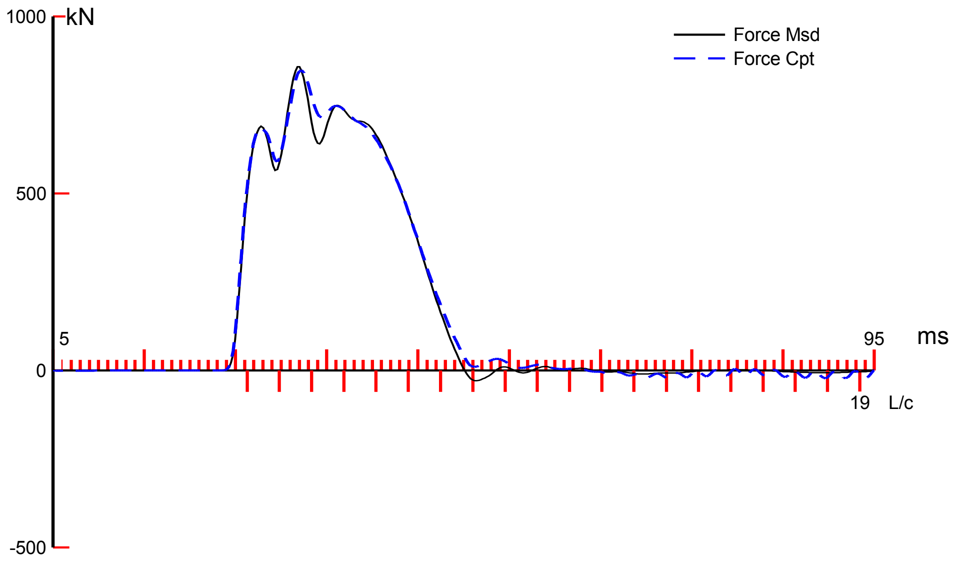
PILE PROFILE AND PILE MODEL

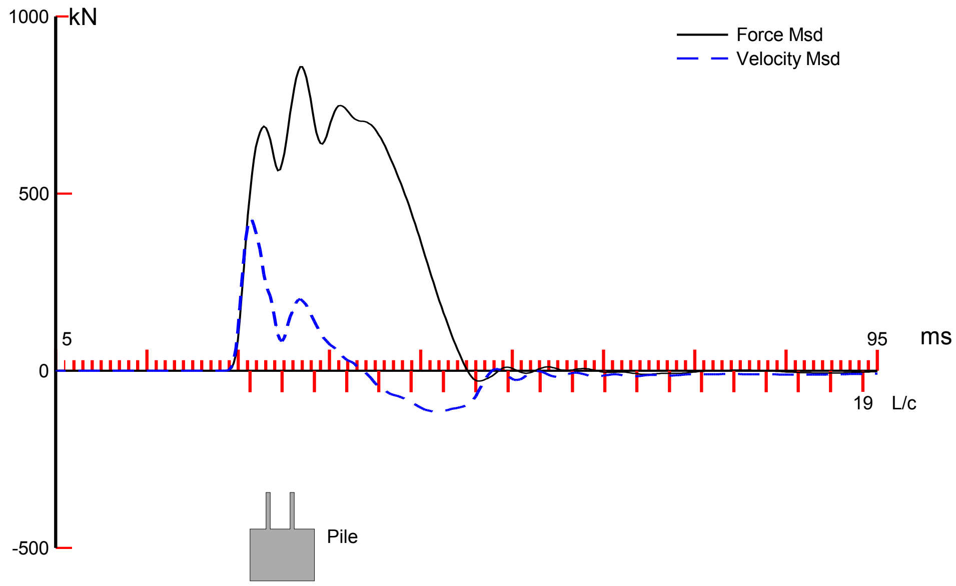
Depth	Area	E-Modulus	Spec. Weight	Perim.
m	cm^2	MPa	kN/m^3	m
10.55	30.82	157462.3	69.137	0.371
16.70	30.82	157462.3	69.137	0.371

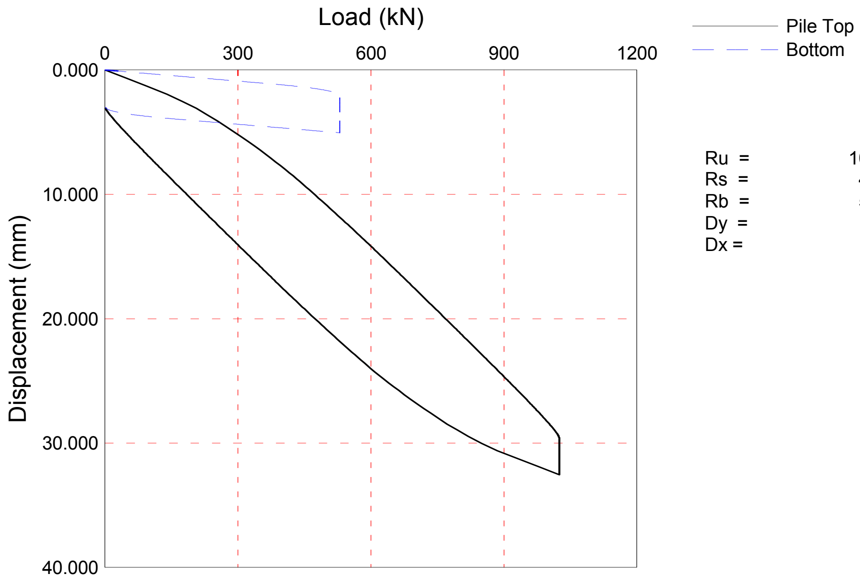
Toe Area 0.011 m^2

Segmnt Number	Dist. B.G.	Impedance	Imped. Change	Tension Slack	Tension Eff.	Compression Slack	Compression Eff.	Perim.
	m	kN/m/s	%	mm		mm		m
1	1.04	102.70	0.00	0.000	1.000	-0.000	0.000	0.371
2	2.09	102.70	0.00	0.000	0.000	-0.000	0.000	0.371
5	5.22	175.30	0.00	0.000	0.000	-0.000	0.000	0.391
6	6.26	102.70	0.00	0.000	0.000	-0.000	0.000	0.371
11	11.48	175.30	14.05	0.000	0.000	-0.000	0.000	0.385
12	12.52	102.70	0.00	0.000	0.000	-0.000	0.000	0.371
16	16.70	102.70	0.00	0.000	0.000	-0.000	0.000	0.371

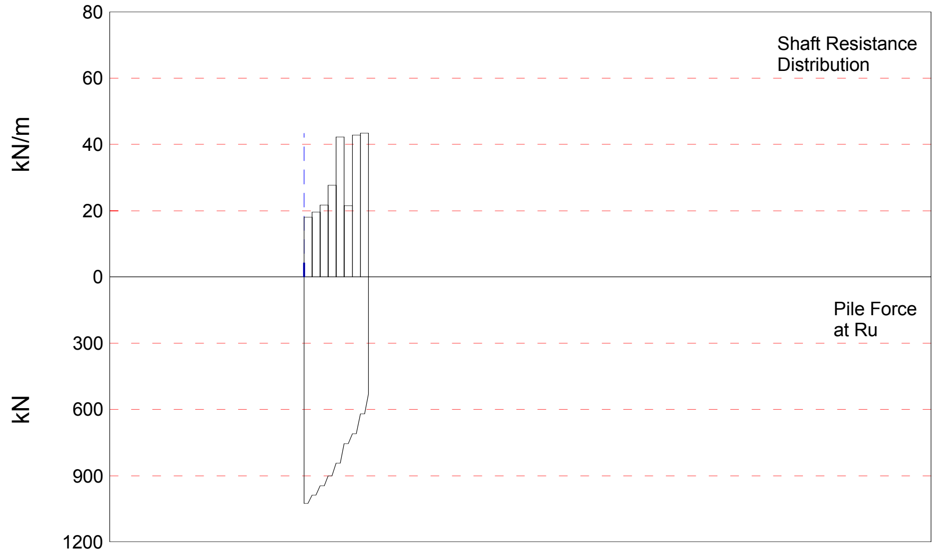
Pile Damping 2.0 %, Time Incr 0.221 ms, Wave Speed 4726.0 m/s, 2L/c 7.1 ms







Ru = 1025.0 kN
Rs = 495.4 kN
Rb = 529.6 kN
Dy = 29.6 mm
Dx = 32.5 mm



STATIC ANALYSIS

Monotonic D-Toe, E-P R-Toe

Step No.	Top Load kN	Top Disp. mm	Toe Load kN	Toe Disp. mm
0	0.0	0.000	0.0	0.000
1	46.6	0.644	3.0	0.009
2	93.1	1.289	6.1	0.018
3	139.7	1.933	9.1	0.027
4	175.0	2.529	12.1	0.036
5	205.8	3.091	15.2	0.045
7	253.1	4.079	21.2	0.063
9	289.4	4.932	27.3	0.081
11	322.4	5.732	33.4	0.100
13	349.6	6.437	39.4	0.118
16	385.2	7.397	48.5	0.145
19	416.2	8.265	57.6	0.172
23	447.0	9.204	69.8	0.208
27	475.1	10.084	81.9	0.244
31	501.3	10.918	94.0	0.281
36	530.9	11.881	109.2	0.326
41	558.7	12.795	124.4	0.371
46	584.7	13.659	139.5	0.416
52	613.6	14.629	157.7	0.471
58	638.9	15.502	175.9	0.525
64	663.2	16.342	194.1	0.579
70	686.9	17.166	212.3	0.633
77	713.8	18.100	233.6	0.697
84	739.7	19.005	254.8	0.760
91	764.8	19.881	276.0	0.824
98	788.9	20.727	297.3	0.887
105	812.1	21.544	318.5	0.950
113	837.6	22.441	342.8	1.023
121	862.4	23.321	367.0	1.095
129	886.0	24.156	390.6	1.167
138	910.2	25.023	414.8	1.249
148	934.4	25.898	439.0	1.339
159	957.6	26.751	462.2	1.439
172	980.6	27.613	485.2	1.557
188	1002.1	28.456	506.7	1.701
212	1020.5	29.270	525.1	1.919
227	1025.0	29.552	529.6	2.054
317	1025.0	30.367	529.6	2.869
407	1025.0	31.181	529.6	3.683
497	1025.0	31.996	529.6	4.498
561	978.4	31.903	526.6	5.041
562	931.9	31.259	523.5	5.032
563	885.3	30.614	520.5	5.023
564	850.0	30.018	517.5	5.014
565	819.2	29.457	514.4	5.005

STATIC ANALYSIS

Monotonic D-Toe, E-P R-Toe

Step No.	Top Load kN	Top Disp. mm	Toe Load kN	Toe Disp. mm
567	771.9	28.468	508.4	4.986
569	735.6	27.615	502.3	4.968
571	702.6	26.816	496.2	4.950
573	675.4	26.111	490.2	4.932
576	639.8	25.151	481.1	4.905
579	608.8	24.282	472.0	4.878
583	578.0	23.344	459.8	4.842
587	549.9	22.464	447.7	4.805
591	523.7	21.630	435.6	4.769
596	494.1	20.667	420.4	4.724
601	466.3	19.752	405.2	4.679
606	440.3	18.888	390.1	4.634
612	411.4	17.918	371.9	4.579
618	386.1	17.046	353.7	4.525
624	361.8	16.206	335.5	4.471
630	338.1	15.382	317.3	4.416
637	311.2	14.447	296.0	4.353
644	285.3	13.542	274.8	4.290
651	260.2	12.667	253.6	4.226
658	236.1	11.821	232.3	4.163
665	212.9	11.004	211.1	4.100
673	187.4	10.107	186.8	4.027
681	162.6	9.227	162.6	3.955
689	139.0	8.392	139.0	3.882
698	114.8	7.524	114.8	3.801
708	90.6	6.650	90.6	3.710
719	67.4	5.797	67.4	3.611
732	44.4	4.935	44.4	3.493
748	22.9	4.092	22.9	3.348
772	4.5	3.278	4.5	3.131

부 록. 4

센서 검교정 성적서

QBTA: ON [ALT-F1/BB=60] Pile Dynamics, Inc. DPF

Pile Dynamics
07-Sep-11 16:09

FS —
10

BN 373
SL 3194/ 3440/ 99

PJ: sn
PN: HOPBAR

TG F2 -- VS
A2 F2 3.3

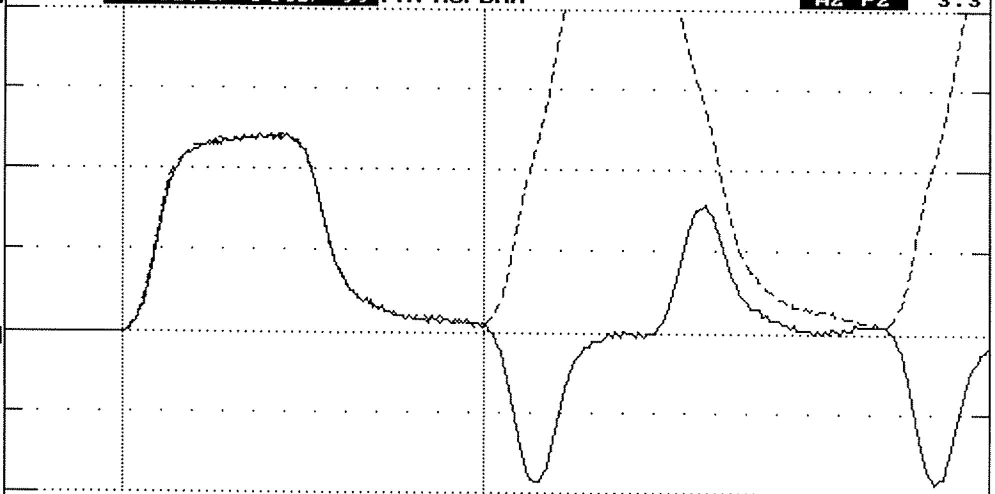
LE 39.6 ft
AR 1.7 in2
EM 30000 Ksi
SP 0.492 K/ft3
WS 16810 ft/s
WC 16862 ft/s

JC 0.40
FM 1.00
VM 1.00

EA/C 30.3 Ks/ft
UN KIPS*0.1
FR 20000 MB 30

DL -29
VT -1
PK 1 TM-PEAK

F1 500
F2 213
A1 999
A2 1120



TS 12 B PD: 27024-075 LP 0.00 ft
TB 8.0 T1 9.5 2L/C 4.7 VA 1000 VE 1022 LI 1.0

VMX= 4.0 FMX= 61 AMX= 149
EMX= 0.2 MEX= 119 FVP= 0.99

ACCEPT SQ-OFF FL-OFF PR-OFF

ACCELEROMETER CALIBRATION N.I.S.T. Traceable

SERIAL NUMBER: 27024

CALIBRATION FACTOR: 1120 G/v

~~PAK (*5000):~~ DATE: 07-SEP-11

PDA OPERATOR: [signature]

contact Pile Dynamics USA
with your questions
tel USA - 216 - 831- 6131
fax USA - 216 - 831- 0916

<-AT:PIEZORESISTIVE OP: alex [ver:4.05] AT:PIEZOELECTRIC->

QBTA: ON [ALT-F1/BB=60] Pile Dynamics, Inc. DPF

Pile Dynamics
07-Sep-11 16:24

FS — 10

BN 415
SL 3194/ 3440/ 99

PJ: sn
PN: HOPBAR

TG F2 -- VS
A2 F2 3.3

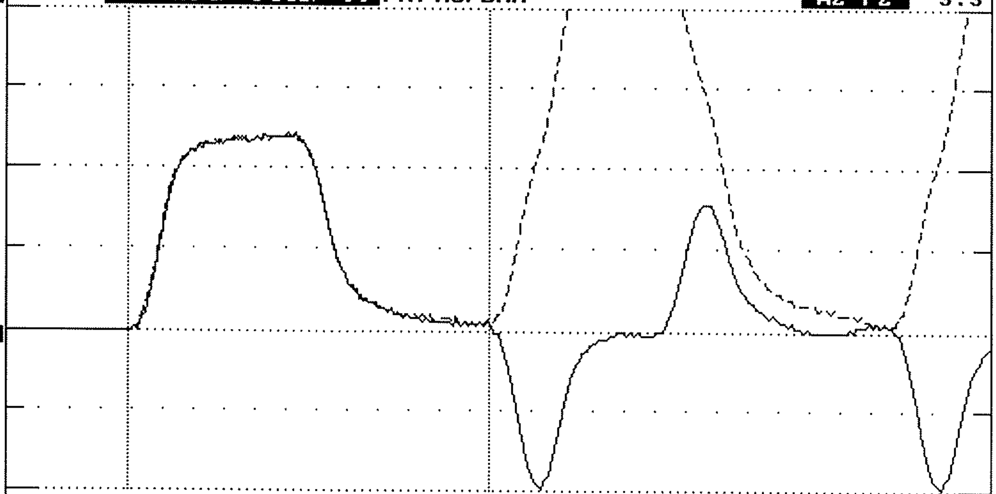
LE 39.6 ft
AR 1.7 in2
EM 30000 Ksi
SP 0.492 K/ft3
WS 16810 ft/s
WC 16862 ft/s

JC 0.40
FM 1.00
VM 1.00

EA/C 30.3 Ks/ft
UN KIPS*0.1
FR 20000 MB 30

DL -30
VT -1
PK 1 TM-PEAK

F1 500
F2 213
A1 999
A2 1125



TS 12 B PD: 27026-075 LP 0.00 ft
TB 8.0 T1 9.6 2L/C 4.7 VA 1000 VE 1022 LI 1.0

ACCEPT SQ-OFF FL-OFF PR-OFF

VMX= 3.9 FMX= 61 AMX= 149
EMX= 0.2 MEX= 119 FVP= 1.00

ACCELEROMETER CALIBRATION N.I.S.T. Traceable

SERIAL NUMBER: 27026

CALIBRATION FACTOR: 1125 G/v

~~PAK (*5000):~~ DATE: 07-SEP-11

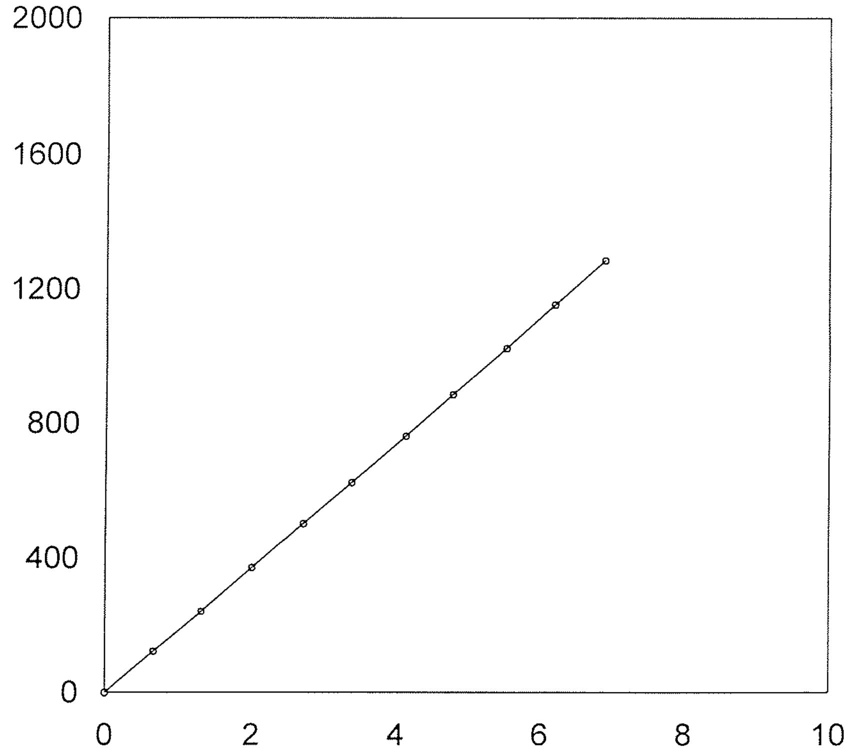
PDA OPERATOR: [signature]

contact Pile Dynamics USA
with your questions
tel USA - 216 - 831- 6131
fax USA - 216 - 831- 0916

<-AT:PIEZORESISTIVE OP: alex [ver:4.05] AT:PIEZOELECTRIC->

Pile Dynamics, Inc.

Transducer D022



PDA Cal Factor (5.0 V) 93.0με/V

Applied Strain (με)	Transducer Output (Volts)
0	0.00
125	0.66
242	1.30
372	2.00
502	2.70
622	3.37
761	4.11
884	4.77
1024	5.51
1153	6.19
1286	6.89

Shunt (60.4 KΩ) 2.5 V

General Factor 323.0με/mV/V

Traceable to N.I.S.T.

Calibrated by: [signature]

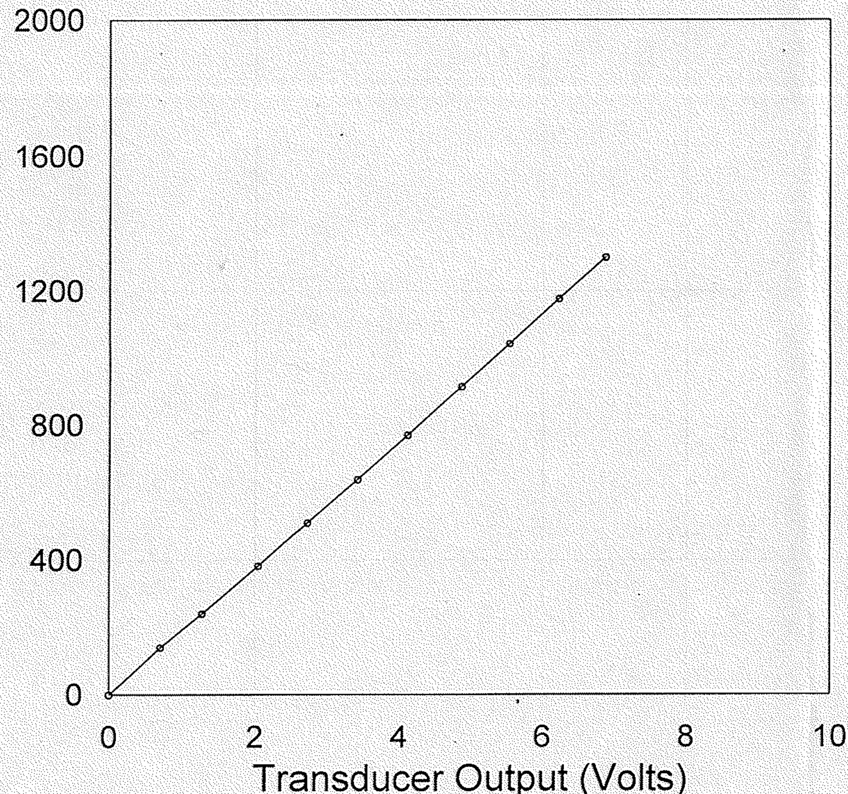
Calibrated on: 13-Sep-2011

Strain Transducer Calibrator System 2009 Version 1.3

Pile Dynamics, Inc.

Pile Dynamics, Inc.

Transducer C832



PDA Cal Factor (5.0 V) 94.2με/V

Applied Strain (με)	Transducer Output (Volts)
0	0.00
141	0.70
242	1.27
383	2.04
511	2.71
638	3.41
771	4.11
914	4.86
1042	5.53
1176	6.22
1299	6.87

Shunt (60.4 KΩ) 2.5 V

General Factor 327.0με/mV/V

Traceable to N.I.S.T.

Calibrated by: [signature]

Calibrated on: 13-Sep-2011

Strain Transducer Calibrator System 2009 Version 1.3

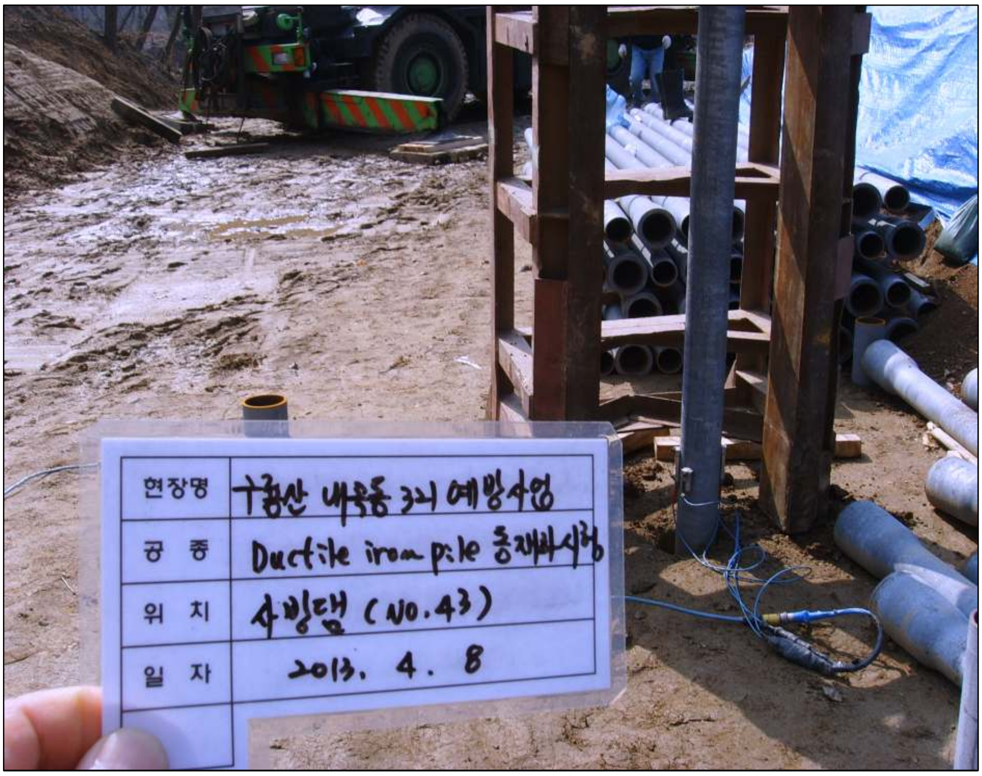
Smart Sensor? X **Yes** ____ **No Smart Chip Programmed by:** GP **on:** 13-Sept-2011 **CRC value** B74E

부 록. 5

현 장 사 진 대 지

현장사진대지

공 사 명	구룡산 내곡동 321 예방사방사업 현장		
위 치	사방댐 NO.43 시험전경1	일 자	2013. 4. 8



공 사 명	구룡산 내곡동 321 예방사방사업 현장		
위 치	사방댐 NO.44 시험전경2	일 자	2013. 4. 8

부 록. 6

품질시험전문기관 등록증 사본

제 2010 - 05호

품질검사전문기관등록증

주　　　소 : 전북 덕진구 팔복동 1가 331-1번지

상　　　호 : 태안특수건설(주)

대 표 자 : 김 대 중

전문분야 : 특 수

업무범위 : 말뚝재하(정재하, 동재하시험)

등록일자 : 2010년 06월 24일

「건설기술관리법시행규칙」 제28조 제3항에 따라 품질검사전문기관으로 등록하였음을 증명합니다.

2010 년 06 월 24 일

익산지방국토관리청장