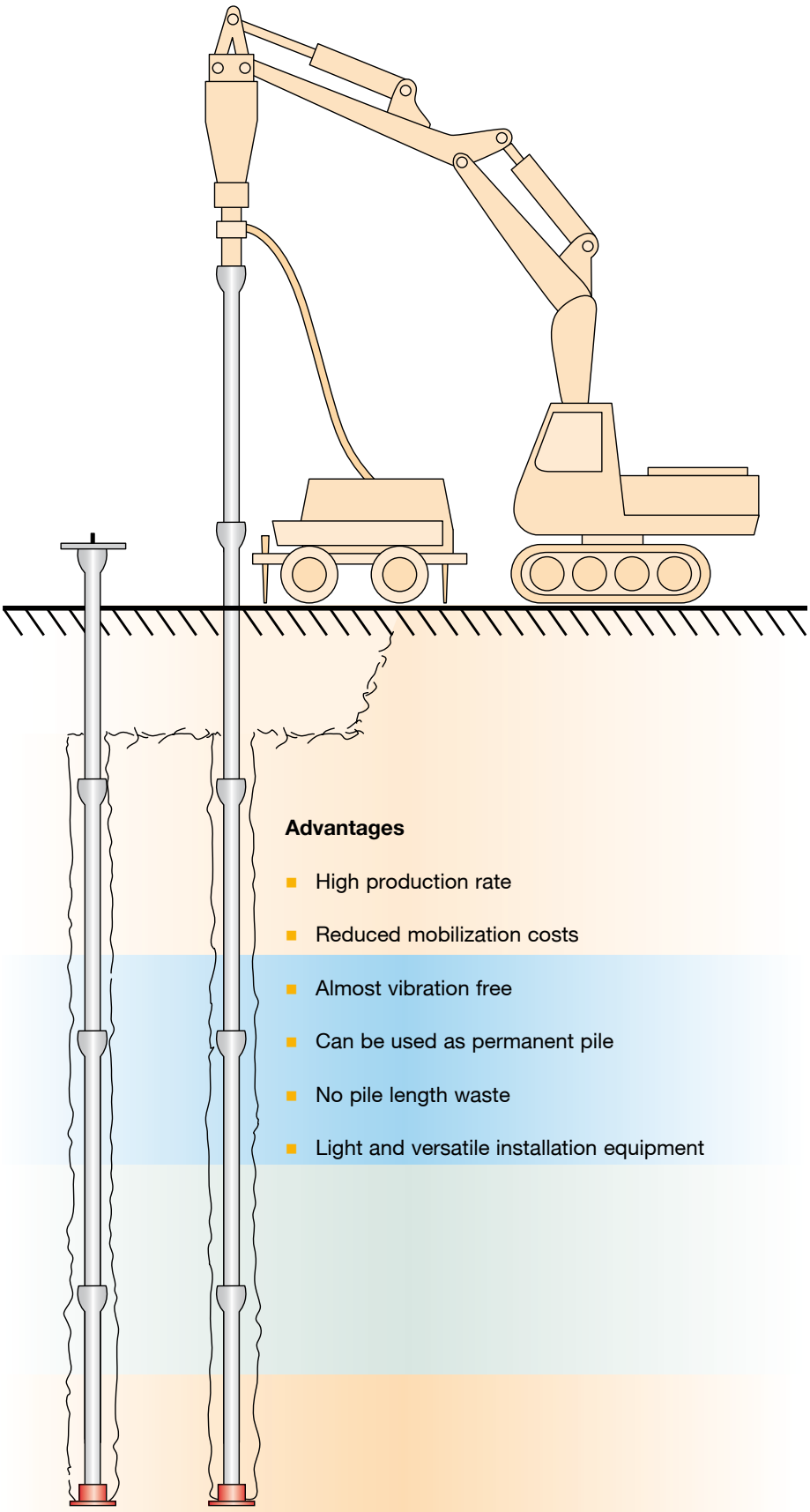
DYWIDAG-SYSTEMS INTERNATIONAL

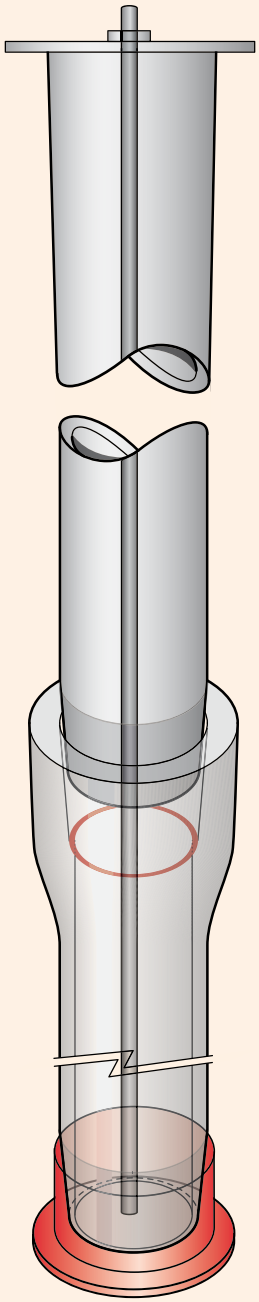
DYWIDAG Driven Ductile Iron Pile



Advantages

- High production rate
- Reduced mobilization costs
- Almost vibration free
- Can be used as permanent pile
- No pile length waste
- Light and versatile installation equipment

Contents



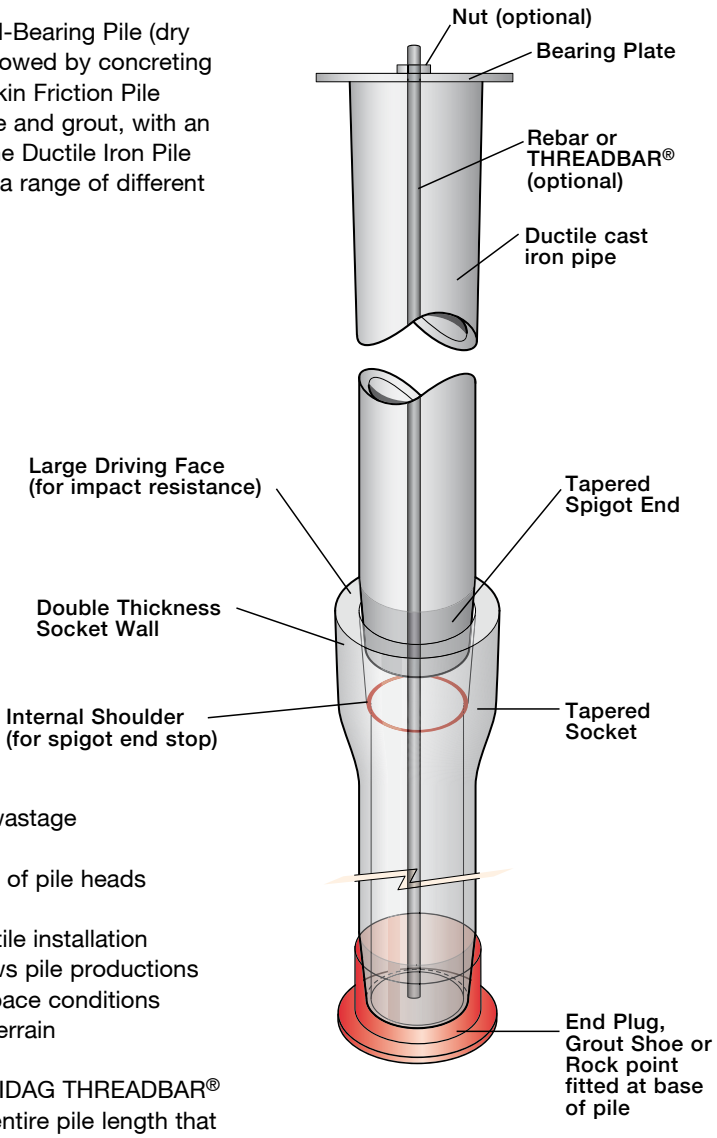
DYWIDAG Driven Ductile Iron Pile

DYWIDAG Driven Ductile Iron Piles

The DYWIDAG Driven Ductile Iron Pile is a driven pile system, utilizing high strength ductile cast iron pipe. 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 Spheroidal 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 oversized shoe), the Ductile Iron Pile can accomondate a range of different ground conditions.



Advantages

- Reduced mobilization costs
- 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
- Optionally DYWIDAG THREADBAR® can be placed entire pile length that together with concrete inside will increase compression load

WARNING!
Ductile Cast Iron Piles are not recommended when boulders and other obstructions are present

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. Pipe verticality is verified visually and with a water level or similar. Piles can be driven also inclined at maximum 45 degrees.

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 embedded into the foundation.

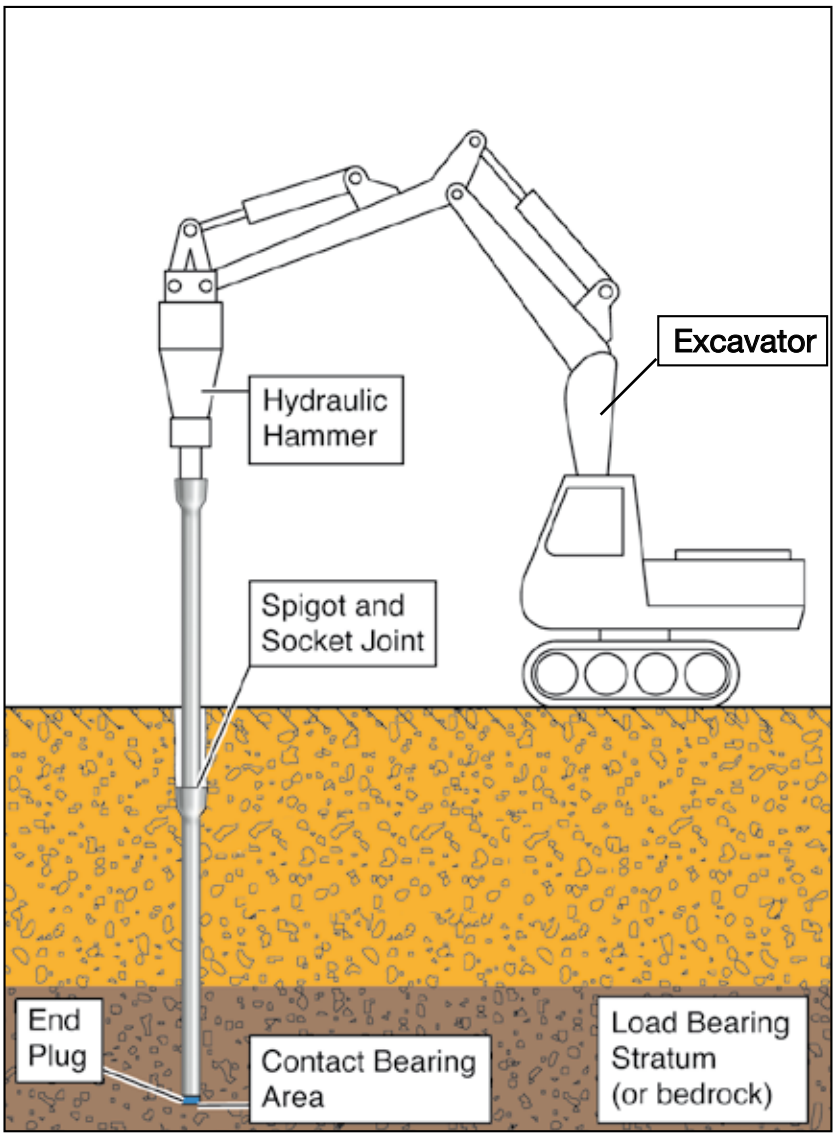
Driven Piles with Subsequent Placement of Concrete (typically end-bearing piles)

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 bedrock. Concrete is then placed into the bore of the pile to give additional strength. A bearing plate with a inserted rebar or DYWIDAG THREADBAR® in the center is added for connection to the foundation.

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 load bearing refusal is defined as the reduced rate of pile penetration, in relation to a sustained driving energy (of the hammer), over a given time. Driven to 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

Penetration Rate per minute	
Pile type	[mm/min] / [in/min]
118	30 / 1.2
170	30 / 1.2

Notes:
1. Values given above are illustrative and obtained from previous projects.
2. 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.
3. The more powerful hammers can be used with the smaller piles, but the rate of penetration for the set remains unchanged.

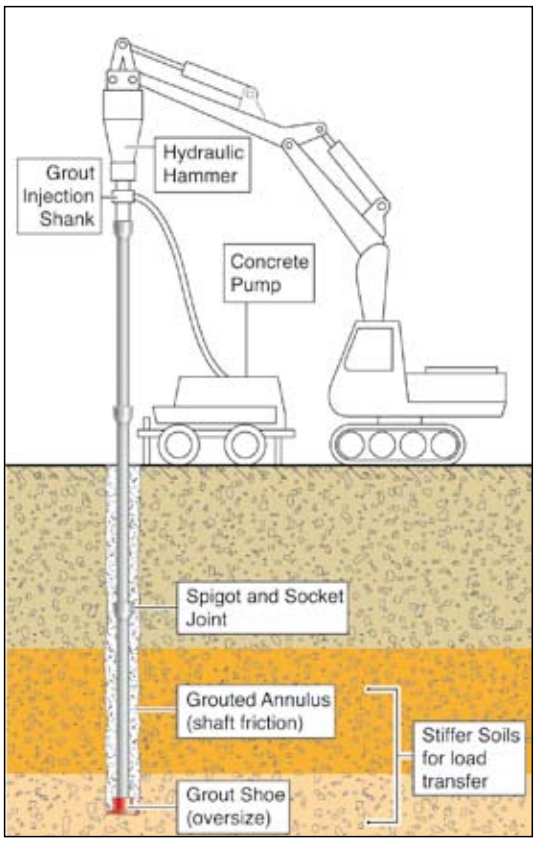
▶ Contact Bearing Area

Pile type	Diameter of End Plug	Contact Bearing Area of End Plug	Pile Socket Diameter
[mm] / [in]	[mm] / [in]	[mm^2] / [in^2]	[mm] / [in]
118 / 4.65	120 / 4.72	11311 / 17.53	160 / 6.3
170 / 6.69	175 / 6.89	24055 / 37.29	218 / 8.58

▶ 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 to fill entire pile length. A high slump concrete with a 3/8 in. aggregate and high fines content is typically used to fill the bore of the pile. Minimum slump of 6 to 7 in. collapse, ensures full placement in the bore. Concrete strength is per project specifications but not less than 3,500 psi compressive strength.

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 oversized grout shoe is fitted to the base of the lead pile section. As the pile is driven into the ground, the oversized 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 friction 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	Soil Grade	SPT	Driving Rate	Skin Friction
		[kPa] / [psi]	[N] Value	[Sec/m] / [Sec/ft]	[N/mm^2] / [psi]
Cohesive	Stiff	75-150 / 11-22	10-14	10-15 / 3-5	0.04 / 5.8
	Very Stiff	150-300 / 22-44	16-30	15-30 / 5-9	0.07 / 10.2
	Hard	> 300 / > 44	> 30	> 30 / > 9	0.1 / 14.5
Granular	Medium Dense		10-30	10-20 / 3-6	0.08 / 11.6
	Dense		30-50	20-30 / 6-9	0.12 / 17.4
	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 are informative only, not used for pile loading. 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 grout with less than $^5/_{32}$ in. sand, to pass through 2 in. hoses and a 1-3/8 in. aperture in the hammer shank.
- Minimum slump: 7 in. to collapse.
- Retarder: 6 hours (open life of grout is essential during pump downtime).

Grout Injection through the pile bore during driving

Cutaway above grout shoe for grouted piles

Accessories

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

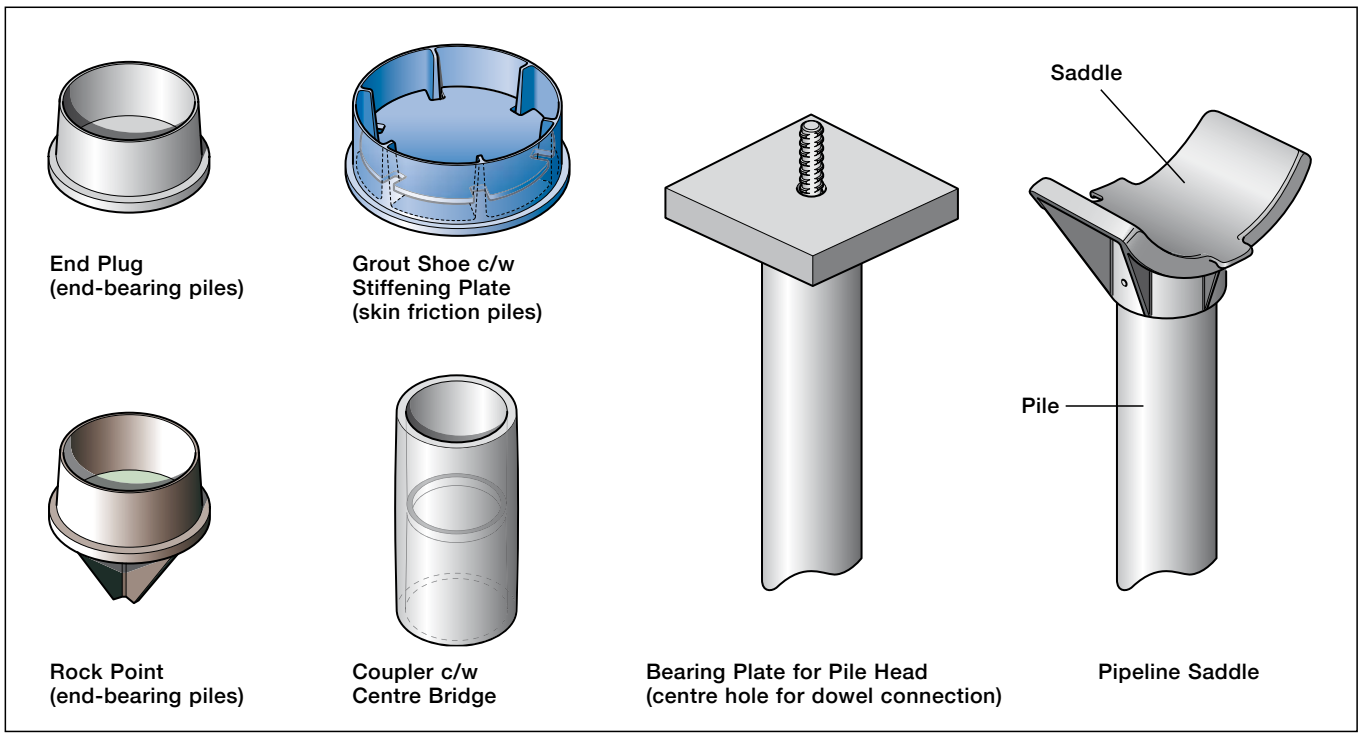
Rock Point
Rock points are an alternative to end plugs, if the end bearing piles are driven through a harder material, e.g. weathered rock

Grout shoe
Grout shoes are used if a grouted friction 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 in. 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.



Accessories
▶ Dimensions

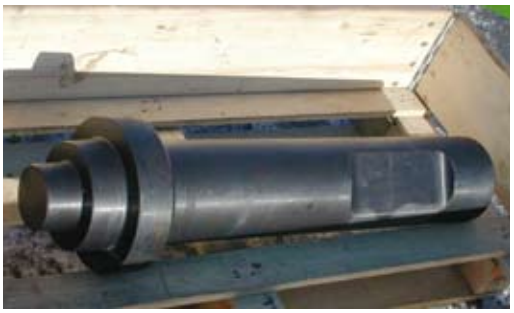
Pile Type	End Plug (O.D.)	Rock Point (O.D.)	Grout Shoe (O.D.)	Recommended Bearing Plate	Optional Coupler (0x0xL)
[mm] / [in.]	[mm] / [in.]	[mm] / [in.]	[mm] / [in.]	[mm] / [in.]	[mm] / [in.]
118 / 4.65	120 / 4.72	120 / 4.72	200 / 7.87	200 x 200 x 41 / 8 x 8 x $1^5/_8$	165 x 400 / 6.5 x 15.75
170 / 6.69	175 / 6.89	175 / 6.89	250 / 9.87	250 x 250 x 41 / 10 x 10 x $1^5/_8$	220 x 450 / 8.66 x 17.71

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.

Accessories and Equipment

Grout injection shank with grout box
Used for installation of grouted friction piles. Sanded grout (with a max. aggregate size of 5/32 in.) 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. One side of the dry driving shank is fitted into the excavator hammer and the other side is fitted into the bell end.

▶ Recommended hydraulic hammers type breakers

(Similar capacity hammers can also be used)

Driven pipe Ø	**118 Ø**	**170 Ø**	**118 Ø**	**170 Ø**
Recommended	Atlas Copco	Atlas Copco	Tramac	Tramac
Model	MB1700	HB2200	V1200	V1600
	(Krupp HM 1000)	(Krupp HM 1500)	(Ingersoll Rand)	(Ingersoll Rand)
Impact frequency (bpm)	320-600	280-550	540-770	405-830
Working weight (lbs)	3,750	4,850	3,460	4,960
Working tool Ø (mm)/(in)	140/5.51	150/5.91	Req. adaptor	Req. adaptor
Impact energy class (ft-lb)	4,000	5,000	5,000	7,500
Operating pressure (psi)	2,320-2,610	2,320-2,610	2,250	2,400
Oil flow (gall/minute)	34-42	37-48	32-45	48-61
Carrier weight (ton)	18-34	26-40	18-30	22-35

Note:
Excavators size is 25 tons (118) or 30 tons (170) and must have sufficient boom / jib height, to handle the hammer length plus the pipe section. Minimum jib height: 25 ft

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.

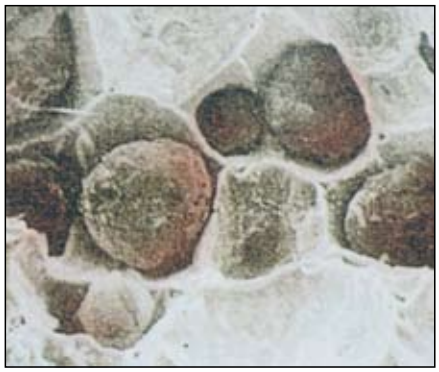
The static pile test provides comprehensive data in respect of the pile‘s performance. Kentledge or anchor piles are required to provide a reaction, against which the pile can be loaded.

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).

Use approved codes and ASTM requirements for testing procedure.

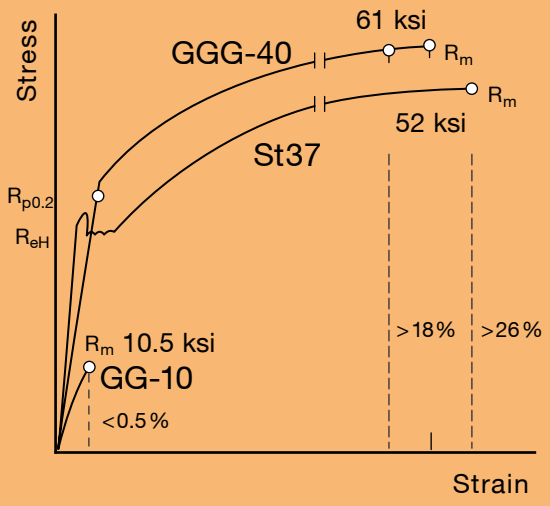
Material

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.



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.



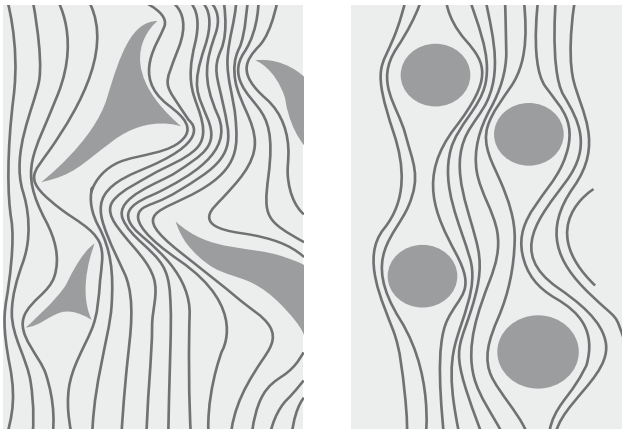
Stress strain diagram of the ductile iron used for the piles in comparison with gray cast iron and constructon steel (left), and magnified microstructure of the ductile cast iron with its typical speroidal graphite (right).

Relation of the Work Lines:

GG-ST37-GGG

Structural Steel St 37 (52 ksi)

Cast iron with lamellar graphite (gray cast iron = GG)



Cast iron with spheroidal graphite (ductile cast iron = GGG)

Course of the strain lines

▶ Specifications

Pipe Dia.	Pipe Thickness	Pipe Length	Weight per Pipe	Cross Section Area	Tensile Stress	Yield Stress	Ultimate Load	Yield Load	Section Modulus	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 / 4.65	7.5 / 0.30	5 / 16.4	105 / 231	2604 / 4.04	420 / 61	300 / 43.5	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 / 43.5	1294 / 291	925 / 208	78 / 4.76	461 / 11.08
170 / 6.69	9 / 0.35	5 / 16.4	186 / 410	4552 / 7.06	420 / 61	300 / 43.5	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 / 43.5	2229 / 501	1592 / 358	199 / 12.14	1683 / 40.43

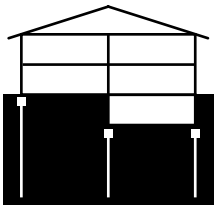
Important: See page 7 for end plug and grout shoe diameter for bearing area calculations

Notes:

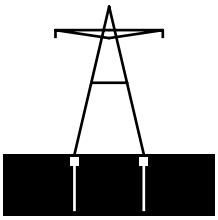
1. Cross sectional areas are based on minimum values.
2. Section Lengths: 5.0m (16.4 ft) for all piles; Overall length of 118 pipe sections = 5.155m (16.914 ft), Overall length of 170 pipe sections = 5.215m (17.11 ft).
3. Working load of Ductile Iron calculated from yield stress x minimum cross sectional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

Applications

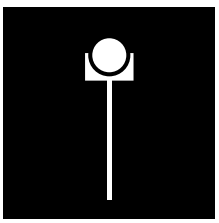
Housing apartments or factory units
With working loads between 112 kips and 290 kips, the DYWIDAG Ductile Iron Piles offer comparable loads to conventional mini piles.



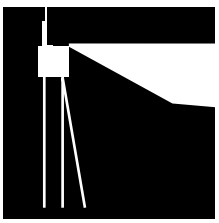
Pylons or Wind Turbines
Power transmission towers can be built on small foundations, which transfer the vertical loads into the ground via the DYWIDAG Ductile Iron Piles.



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.



Corrosion Assessment for DYWIDAG Ductile Iron Piles

Non-grouted end bearing 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. The corrosion rate of cast iron is generally lower than steel and the casting crust is an additional barrier which slows corrosion.

Corrosion rates depend on 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 grouted friction pile (external annulus of the pile is fully grouted)

Test site: grouted driven piles after removal of soil nail around them

References

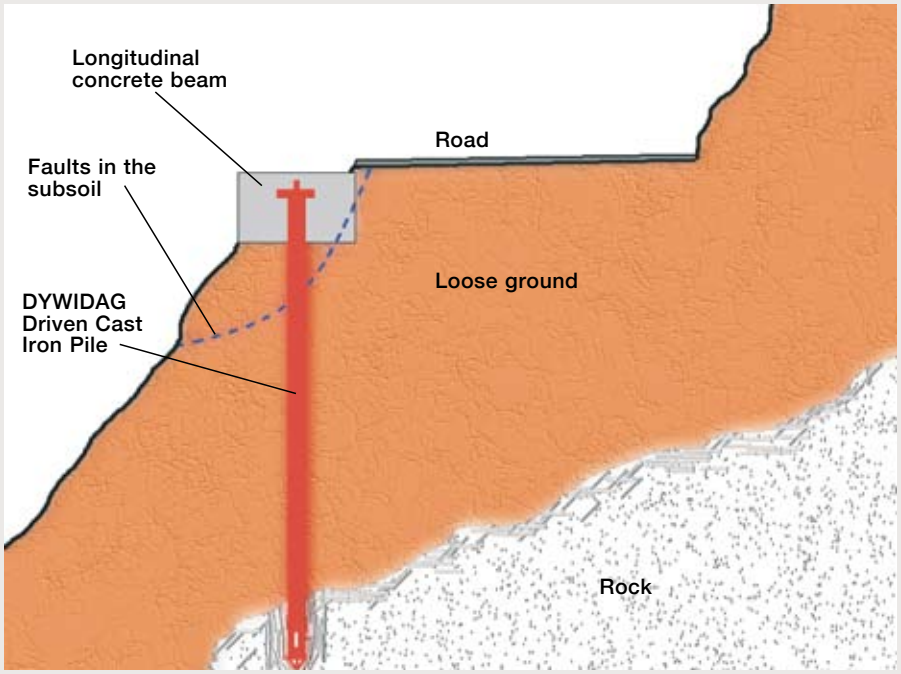
Sewer Line on Piles, Erbach

Client Motz Construction Co.
DSI Scope Supply of 20 DYWIDAG Ductile Iron Piles, 200 m, non-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 Scope 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 Scope Supply of 865 DYWIDAG Ductile Iron Piles, 6.500 m, skin-grouted

References

Furnishing House Gamerdinger, Bˆblingen

Client Keller Grundbau
DSI Scope Supply of 332 DYWIDAG Ductile Iron Piles, 3.500 m, non-grouted

Housing Apartments, Monaghan, Ireland

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

References

L'Avant Mer Resort, St Lucia, West Indies

Luxury 4-Story Condominium Units with Garden and Marina View Built on End Bearing DYWIDAG Driven Ductile Cast Iron Pile Filled with Concrete

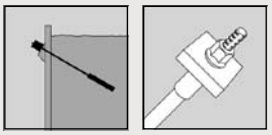
Client NH International (Caribbean), Ltd, Trinidad, West Indies
DSI Scope Technical assistance and DSI supplied more than 3000 m of 170/10.6mm pipe

Coombedown, near Bath, UK

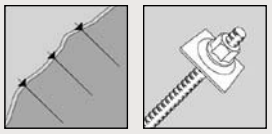
Client Ritchie Brothers Ltd., UK
DSI Scope Supply of 118/7.5 DYWIDAG Ductile Iron Piles for crane bases

Additional Geotechnical Products from DSI

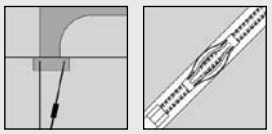
DYWIDAG Bar Anchor Systems .....



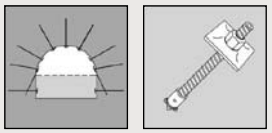
DYWIDAG Soil Nails .....



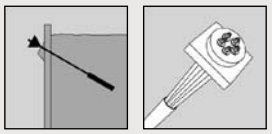
DYWIDAG Micropiles .....



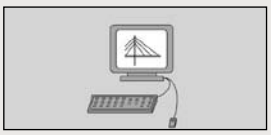
DYWI® Drill Hollow Bar Systems .....



DYWIDAG Strand Anchor Systems .....



DYNA Force Elasto Magnetic Sensor .....



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