PILE DRIVING
5-393.150

5-393.151 GENERAL

Pile driving inspection deals not only with properties of materials but also with properties of soils. A working knowledge of soil classification, soil characteristics, mechanics of pile hammers, dynamic and static loads, specifications, plan reading, welding, and materials inspection are some of the desirable prerequisites for a proficient pile driving inspector.

The tendency seems to have been, in some cases, to assign pile driving inspection to the least experienced personnel. While there are situations where the driving is quite routine, such as when driving steel piles through relatively low resistance soils to end bearing on a level plane of bed rock, this is the exception. Usually pile driving inspection involves the use of sound judgement which can only be attained through training and experience. The inspector must determine the acceptability of the pile before it is placed in the leads, observe the performance of the hammer, determine when pile damage or breakage has occurred or is likely to occur, and must make a judgement regarding acceptable penetration and bearing capacity.

Since pile driving is a hazardous occupation, the Engineer and the inspector should take every precaution within reason to reduce the potential for accidents. The inspector should wear a hard hat, hearing protection, and good, hard toed, high top shoes. When treated timber piles are driven, s/he should also wear protective goggles, and clothing which will provide maximum cover. Cold cream or other protective film should be applied to exposed skin surfaces to prevent burns from creosote; and stay on the windward side of the pile, when possible.

Inspectors should observe the pile closely during driving for any evidence of failure. Many failures can be readily detected in time to avoid a disastrous accident, and some can be detected in time to save the pile. If the head of a timber pile starts splitting and the penetration and bearing are satisfactory, driving should be stopped.

Timber piles with knot clusters, bends, sweeps or bows, or other irregularities, may fail suddenly and without warning. Therefore, it is prudent to be alert to these conditions and make proper allowances for them.

Electrocutions have occurred when operating near power lines, particularly high voltage lines. It is advisable to check with the power company regarding “safe distance” or to have the power shut off temporarily when it is necessary to drive piles in the vicinity of their lines. Electricity may “jump” a meter (3 feet), especially in high humidity.

Unprotected excavations are dangerous at all times, but particularly so during pile driving as the intense vibrations caused by the pile hammer are transmitted through the pile into the ground. Insist on well constructed cofferdams, shoring or adequate back-sloping before entering a confined excavation.

Pile hammers, particularly when combined with long leads, long booms, and long, heavy piles, provide potential for tipping the crane or buckling the boom. The inspector should be constantly alert to the possibility of an accident when these conditions exist, and should stay clear of danger areas as much as possible.

Life jackets must be worn when working over large rivers or lakes and some means of rescue must be readily available such as boat and motor, life lines with life buoys, ladders, etc. The Contractor will be governed by regulations set forth by the Department of Labor and Industry, Occupational Safety and Health Administration, but common sense and some forethought could pay off as well.

Inspectors should wear ear protection devices, either plugs or muffs, when they are in close proximity to pile driving operations. The following charts show sound levels and durations which may cause loss of hearing:

DECIBEL CHART

	dB	Source
Extreme danger	155	Rifle blast; close-up jet engine; siren
	140	Shotgun blast (to shooter); nearby jet engine
	120	Jet airport; some electronic music; rock drill
Probable permanent hearing loss at these levels	115-125	Drop hammers; chipping hammers
	110-115	Planers; routers; sheet metal speed hammers
	99-100	Subway; weaving mill; paper-making machine
	90-95	Screw machines; punch press; riveter; cut-off saw
Possible damage	80-95	Spinners; looms; lathes
	80	Heavy traffic; plate mill
	70	Busy street
	60	Normal speech
	50	Average office
	45-50	Low conversation
	20-30	Quiet city apartment; whisper; comfortable sleeping limit
	15	Average threshold of acuity; leaf rustling
	0	Threshold of acute hearing (0 dB is
	1	0.0002 dynes per sq. cm)

Sustained exposure to dB above the upper levels may cause vibration of cranial bones, blurred vision, even weakening of body muscular structure. Frequencies of 500-2,000 Hz are most critical to noise-inducing hearing loss.

When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered rather than the individual effect of each. Exposure to impulsive or impact noise should not exceed 140 dB peak sound level.

Protection against the effects of noise is required by federal regulations when the sound level exceeds those shown below:

Duration per day, hours	Sound Level dB Slow Response
8	90
6	92
4	95
3	97
2	100
1-½	102
1	105
½	110
¼ or less	115

Authorities generally agree that loss of hearing is caused by prolonged exposure to noise rather than old age. Loss is probably caused by progressive destruction of nerve ends when the sound level exceed 80 decibels (dB). Definite danger of permanent impairment exists at levels above 95 dB and continued exposure to this loudness level in the 300 to 1200 Hz range makes personal hearing protection necessary.

Ear protectors may be secured from engineering stores in the District office.

5-393.152 USE OF SURVEY SHEET

The survey sheet or sheets attached to the bridge plan includes soils information in the form of borings and soundings. Except in the case of driving through soft overburden to rock, both soundings and boring logs are essential. This information, although intended primarily for the designer, can be very beneficial to the inspector and to the Contractor and it behooves the pile driving inspector to study it carefully.

Careful study of the soils information will indicate depths at which:

1. hard driving will likely be encountered
2. rocks and boulders may cause problems
3. weak soil layers which should be penetrated,
4. layers of dense material which may be of adequate depth to support pile loads without the necessity of driving through them.

The soil borings are now almost always taken with a standard apparatus (standard penetration test - SPT), consisting of a 63.5 kg (140 lb) mass which is dropped 760 mm (30 in.). Some older bridge plans show soundings, using a 22.7 kg (50 lb) mass with a 600 mm (24 in.) drop. Sounding rods, with couplings at the end of every 1200 mm (4 ft) section, tend to pick up resistance in addition to that which the special point encounters. Therefore, the blow count per 0.3 meter (1 ft) almost always increases with depth for that apparatus, whereas with the standard penetration equipment only point resistance is measured.

It is also important that the soils information is available for some distance below the anticipated pile tip elevation to assure a supporting layer of adequate depth.

Soil types are generally indicated on the survey sheet by the use of letters, to conserve space. Following is a key to the textural soil classification system:

Organic	Org.
Sand or Sandy	S
Silt or Silty	Si
Clay	C
Loam or Loamy	L
Fine	F
Medium	M
Coarse	Cr.
Gravel	G.
Till	T
Plastic	Pl.
Slightly plastic	Slpl

Combination of the above can be written as follows:

Silty Clay Loam	SiCL
Clay Loam	CL
Silt Loam	SiL
Slightly plastic fine Sandy Loam	Slpl FSL
Loamy Sand	LS
Coarse Sand	Cr.S.
Sand and Fine Gravel	S & FG
Sandy Loam Till	SLT

Peat, muck, marl or any special swamp material designation should be written out, and the color of the material should be abbreviated as follows:

Black	blk.
Brown	bwn.
Gray	gr.
Yellow	yel.
Dark	dk.

Other colors will be written out.

Notes stating "water encountered" do not necessarily imply water table elevation as the drilling process requires either a cased hole or use of "drilling mud" which may cause changes in water elevations.

5-393.153 PILE NOMENCLATURE

Pile (Webster's Dictionary): *"A long slender member usually of timber, steel, or reinforced concrete driven into the ground to carry a vertical load as in the case of a bearing pile, to resist a lateral force, as well as a vertical force, as in the case of a batter pile (which is driven at an angle with the vertical), or to resist water or earth pressure as in the case of a sheet pile."*

This section of the manual will cover only bearing piles, which for our purpose includes pile bents, test piles, foundation piles, and trestle piles, but not sheet piles. For Mn/DOT bridge structures, piles are used:

1. whenever the soils at and below the elevation of the bottom of the footings are too weak or too compressible to provide a stable foundation for a spread footing, or

2. where there is danger of erosion or scour such as in streams, or

3. where there is a thrust against the walls or columns which might result in horizontal movement.

Piles are supported by end bearing on rock, or other dense formations such as gravel or hard pan; or by friction between the surface of the pile and the adjacent soil; or by a combination of end bearing and friction. In order to design a pile foundation, it is necessary for the designer to know what type of support can be expected, which in turn necessitates information that can only be obtained by adequate borings and soundings.

Friction piles are usually displacement type piles such as timber, concrete, or cast-in-place concrete utilizing steel shells, which obtain most of their load carrying capacity through friction resulting from perimeter contact with the soil. The required length of this type of pile is difficult to predict. Load tests may be required to ensure adequate bearing. Steel H-piles are sometimes used as friction piles, particularly when the soil borings indicate the presence of rocks and boulders, or when considerable resistance buildup is anticipated such as in medium to heavy plastic soils.

End-bearing piles are those for which the tip of the pile is driven to rock, or a short distance into hard pan or dense gravel adequate to carry the design load without reliance on friction. Almost any type of pile can be used as an end bearing pile, but because of their high load carrying capacity and their capability of penetrating relatively dense soils, steel H-piles are often selected. However, cast-in-place concrete piles can also be used as end bearing piles when the soils information indicates that they can be driven to the required tip elevation, or when they are desired for the sake of appearance, as in a pile bent. Drilled shafts may also be used for end bearing piles but are generally more expensive than steel H or cast-in-place concrete piles.

Friction-end-bearing piles are those which derive their load-carrying capacity by a combination of friction and end bearing. Justification for high loads on this type of pile may require pile load tests. Cast-in-place concrete piles, utilizing steel shells, are probably best suited for this type of foundation design, although either timber or steel H-piles may also be used.

Timber piles are displacement piles and generally obtain most, if not all, of their load carrying capacity through friction. Timber piles are seldom used on trunk highway bridges due to their relatively low capacity. The use of timber piles is also prohibited from use in pile bent substructures located in streams or rivers due to their low resistance to lateral loads induced by ice flows or debris. The most common use of timber pilling on trunk highway bridges is for abutments of temporary bridges. Specification 3471 specifies the species that may be used for the various applications, as well as other requirements such as straightness, knots, peeling, twist, density and dimensions. Timber piles are classified by 3471 in three categories: (1) Untreated Foundation Piles Below Water Level; (2) Untreated Trestle Piles; (3) Treated Piles.

1. Untreated Timber Foundation Piles are timber piles which do not require a preservative treatment because they will be totally and permanently below the water level, therefore no wetting and drying cycles. Other considerations in specifying the use of untreated timber would be that the water be free of acid or alkaline wastes and from harmful marine life.

2. Untreated Timber Trestle Piles are not used for highway structures, except for temporary trestles and bypasses.

3. Treated Timber Piles are by far the most commonly used timber piles for our structures. When treated in accordance with Spec. 3491, they have excellent resistance against rot, acids and alkaline wastes, marine life, bacteria, and wetting and drying cycles. Because of their resistance to attack from the above-named sources, treated timber piles can be used above or below water and under most types of adverse conditions. A booklet by Dames and Moore, published by American Wood Preservers Institute, entitled Pressure Treated Timber Foundation Piles, is a very good source of information on this product.

Steel H-piles are rolled sections which are made up in a variety of sizes and from various grades of steel. Currently Mn/DOT Specifications require ASTM A572M/A572 Grade 345 (50) steel, and sizes commonly used are HP 250x62 (10 x 42) and HP 310x79 (12 x 53) (HP indicates an "H" section pile, 250 (10) indicates 250 mm (10 in.) in cross section depth, and 62 (42) indicates a mass of 62 kg/m (42 lbs/ft)). Steel H-piles, because of their comparatively small area in cross section, displace a minimum volume of soil. Hence, steel H-piles can be driven through fairly dense material, even into soft rock, making them a popular choice when these conditions are anticipated. They have great strength and toughness and can be driven to depths exceeding 61 m (200 feet) by splicing additional sections on to those already driven.

Pile tip protection is sometimes required where driving conditions are difficult and there is concern about damage to the pile tip. Steel H-piles are generally driven with manufactured pile tip protection welded to the end. The pile tip protection also helps to "seat" the pile when driven to bedrock or into hard pan materials. In most cases steel H-piling is used where difficult driving conditions are anticipated but occasionally conical points are welded to steel shell piling for this purpose. Approved tip protection will be listed in the special provisions.

ASTM A6/A6M is the defining standard for H-shapes. Bethlehem Steel Corporation's Booklet 2196, and United States Steel Corporation's ADUCO 25002, both entitled Steel H-Piles, are good informational sources on this product, also.

Where steel H-piles are required on the plans, thick wall steel pipe is often allowed in the special provisions as a contractor's option. This pipe, with a minimum wall thickness of about 13 mm (½ inch), is made of high strength steel for use in exploration drilling for oil. Material available for bridge construction has been rejected for its intended oil field use but is suitable for piling. These pilings are very resistant to damage because of their cylindrical shape and high strength steel. Welding is more difficult than for A709/A709M Grade 250 (36) steels and preheating is required. The preheat temperature is dependent on carbon equivalent content which is determined from test data by the ITW Carbon Equivalent Formula (assuming zero cobalt content) as follows:

$$Cq = C + Mn/6 + (Cr + Mo + V) / 5 + Ni / 15$$

A chemical analysis for carbon, manganese, chromium, molybdenum, vanadium and nickel must be furnished by the manufacturer. Contact the Mn/DOT Metals Quality Engineer in the Bridge Office for more information.

Pile tip protection is not required for thick wall pipe as the material strength is about equal to a cast steel point. When available, the material cost per meter (foot) is generally less than an equivalent H-pile and where pile points are necessary for H-piling, the elimination of these points is an additional cost saving factor. The piles are driven open-ended and filled with sand or concrete after driving has been completed.

Cast-in-place piles of the type currently being specified require that steel shells (generally with closed ends) be driven to required penetration and bearing, checked for buckling, then filled with concrete. The thickness of the shell must not be less than the minimum specified, and must be increased if necessary to withstand the required driving. Unless noted otherwise, the minimum wall thickness is specified in 3371. The Specifications permit the Contractor the option of using either tapered or cylindrical shells with certain specific requirements regarding yield strength, wall thickness, diameter, and capability to withstand driving to substantial refusal.

Cast-in-place concrete piles of uniform cylindrical section will cause more displacement than will timber piles or tapered cast-in-place piles. However, since the pile shell is of constant diameter with a relatively smooth outer surface, friction does not build up as readily along its surfaces as in the case of tapered piles. Because of the generally larger diameter at the tip, cylindrical piles are likely to develop greater end bearing capacity when dense soils are encountered. One of the advantages of this type of pile is the ability to visually inspect for straightness and for damage after driving.

Unless conical points are specified, steel shell pile will have a steel driving "shoe" welded to the base. The shoe thickness for 310 mm (12 in.) and 406 mm (16 in.) is 19 mm (3/4 in.). The shoe is simply a steel plate that keeps soil out, and the pile remains watertight. The shoe shall not extend more than 6 mm (1/4 inch) outside of the periphery of the shell.

The most common cast-in-place pile sizes for bridge designs in Minnesota are 310 mm (12 in.) O.D., 324 mm (12 3/4 in.) O.D., and 406 mm (16 in.) O.D., although 254 mm (10 in.) O.D., 508 mm (20 in.) O.D., and 610 mm (24 in.) are sometimes used.

Precast concrete piles are rarely used for Mn/DOT structures because of their mass and because of the difficulty encountered when splicing becomes necessary. Except for their driving mass, their performance can be compared with the cast-in-place concrete piles. Greater care must be exercised during driving to keep the pile and the pile hammer in proper alignment, so that the hammer blows will be delivered squarely. A pile cushion made of plywood, hardwood or a composite of plywood and hardwood materials is required to protect the pile head during driving. Hammer blows delivered to the top of a concrete pile slightly out of alignment with the hammer are likely to cause damage by shattering the concrete on the side receiving the impact.

Drilled shafts (also called caissons or drilled piers) are used occasionally for deep foundations although their use has been limited to special cases where end bearing can be obtained. Costs for drilled shafts are higher than for driven piling at the present time and only a few contractors have the special equipment required to place them. Plans and special provisions will provide detailed information on this type of piling. Drilled shafts are installed by augering a hole (casing may be necessary and is generally mandatory below water) to the depth specified. A series of holes of gradually decreasing diameter is often necessary where casings must be used. Careful inspection of the drilled hole and of concrete placement is necessary.

For our purpose, test piles are used for determining the "authorized" length of the remaining piles for a structure, or a portion of a structure. They are almost always carried as a separate pay item (or items if more than one length or type are involved) in the contract. The contractor usually includes a large part of his/her fixed costs in the price bid for test piles, because of the possibility that the remaining piles may be reduced in length. This results in a loss to the contractor if fixed costs were included in the bid price for “Piling Delivered” and “Piling Driven”. The Specifications provide that: “Test piles will not be eliminated from the contract, unless all piles for the unit in which they are to be driven are eliminated, or unless mutually agreed upon by the Contractor and Engineer.” Information gained from driving test piles should be compared with the soundings and borings on the Survey Sheet of the Plans when attempting to authorize foundation pile lengths.

Penetration usually is considered to be the length of pile below cut-off elevation; that is, the total length of a pile which will remain in the structure. The term penetration is also used in connection with “penetration per blow”, which is generally determined by taking an average of several blows of the pile driving hammer, or by counting the blows per 0.25 m (1 ft), and which is plugged into a capacity formula for determining the bearing capacity.

“Pile Placement” is a pay item used when test piles are not provided. Pile lengths are not authorized and the Contractor must drive all piling to substantial refusal or bearing satisfactory to the Engineer. The “Pile Placement” item includes all costs of equipment, splicing, drive shoes or tip reinforcement, end plates, cut off, and other costs except furnishing pile material and driving the pile. Furnishing and driving is paid for as “Piling Furnished and Driven”.

5-393.154 STORAGE AND HANDLING OF PILES

When handling treated timber piles, use rope slings. Avoid the use of chain slings, hooks, or other methods that will break through the protective treatment. Avoid dropping the timber piles and bruising or breaking the outer fibers. It is advisable to stack treated timber piles for storage on timber sills so that the piles may be picked up without hooking.

The application of preservative oil to cuts, holes and abrasions should not be minimized. This treatment is vital to the life of the timber pile and is important enough to warrant careful attention.

Concrete piles must be handled with care. It is very easy to cause cracks by indifferent handling. Cracks may open up under driving, and may spall and “powder” to such an extent as to seriously lessen the strength or life of the pile. Shock, vibration, or excessive deflection should be avoided by using proper equipment and thoughtful handling. When piles are picked up with adjustable slings, blocking should be used to prevent breaking off the corners. Unless special lifting devices are attached, the pick-up points shall be plainly marked on all piles before removal from the casting bed and all lifting shall be done at these points. If the piles have been allowed to dry after curing, they shall be wetted at least 6 hours before being driven and shall be kept moist until driven.

When loading steel H-piles at the fabricator's plant, the individual piles must be placed with webs vertical and blocked so that the flanges will not be bent. There is perhaps greater danger of damage to the steel when it is unloaded from the car, hauled to the work, and unloaded from the truck or trailor at the site. The project inspector must observe that the handling methods at the jobsite are performed carefully to avoid damage to the piles.

5-393.155 SPLICING PILES

Welding of piling splices must be made by properly qualified welders. For most field welding, Specifications require a welder to have passed a Mn/DOT qualification test. The welder should have a valid Mn/DOT welder certification card. The welder must show proof of certification when asked. If the card is current, this is acceptable as sufficient evidence of a welder's ability. The inspector should verify that each welder is properly certified. Information on welder certification and verification of certification can be obtained from the Structural Metals Inspection Unit.

Those responsible for administering the construction contract are also responsible for materials certification for steel piling. The inspector should retain all copies of purchase orders, test reports and Form 2415 listing heat numbers and condition of piling. The Mn/DOT Structural Metals Engineer can help answer questions regarding welder qualification, welding work in general or sampling and testing of steel piling.

5-393.156 JETTING AND PREBORING

Jetting is a means of obtaining pile penetration through elimination or reduction of resistance at the pile tip by the use of water, air, or a combination of these two media, delivered by pressure through hoses and pipes. The soil is eroded below the tip of the pile, often permitting penetration merely by the dead mass of the pile and the hammer. It is particularly effective when displacement type piles are to be driven through dense fine sand to desired penetration in firm soils below, but should not be used in embankments or other areas where it would tend to destroy densities which have been purposely built into the soils. Also, unless good judgement is exercised, jetting could destroy the bearing value of piles already driven, especially when piles are closely spaced or when they tend to drift away from their prescribed course. Water jetting has been useful as an aid to driving displacement types of piles in sand formations in streams where water is readily available and pile penetration is equally as important as bearing capacity.

Although the Specifications currently specify certain requirements pertaining to the jetting equipment, the prime objective should be that of performance. Equipment which would not be satisfactory in some cases may be entirely adequate in other cases. The booklet by Dames and Moore, referred to previously under Treated Timber Piling, describes various methods of jetting in considerable detail.

Preboring, as the word implies, is merely boring holes through or into soils prior to driving piling. It is perhaps the most expedient and popular method of obtaining pile penetration of displacement piles through or into high density embankments, or through crusty upper stratum that must be penetrated because of weak underlying soils. Preboring is generally accomplished by the use of a power auger of a diameter larger than the maximum diameter of the piles to be driven, mounted on the crane used for the pile driving or on separate equipment. There are many variations of preboring equipment; some of these are covered in considerable detail in the previously mentioned booklet by Dames and Moore entitled Timber Foundation Pile Study.

5-393.157 DRIVING EQUIPMENT

The drop hammer is the original pile driving hammer which has been used in one form or another for many years. It consists of a steel ram, forged to a shape that will permit it to be confined within a set of leads, and to be raised to desired height and dropped on the top of the pile. This type of hammer is now rarely used because of its slow operation and because the velocity at impact often results in pile breakage before the required penetration and bearing have been obtained. We have, through our Specifications, increased the requirements for hammer mass and reduced the height of fall, but even further adjustments are desirable. Greater efficiency and less damage would result from the use of a 2000 kg (4400 lb.) ram with a 1500 mm (5 foot) drop than from a 1000 kg (2200 lb.) ram with a 3000 mm (10 foot) drop. It is generally necessary to provide a steel pile cap to fit over the top of the pile, with a shock block on the top of the cap to absorb part of the impact.

Although seldom used today, Single Acting Steam and Air Driven hammers replaced the drop hammer and were used to build many of the bridge and structures that are still in use today. Both of these hammers are basically drop hammers. The difference is that the ram (striking part) is encased in a steel frame work and is raised by steam or compressed air delivered through hoses from boilers or air compressors. The frequency of the blows is considerably higher than with a drop hammer, the ram mass is usually greater and the height of drop is considerably less. The increased frequency of the delivery cycle permits less time for the soils to settle back around the pile between blows, thereby further increasing the efficiency.

A typical Single-Acting Steam or Air-Driven Hammer utilized a 2000 kg (4400 lb.) ram with a 900 mm (3 foot) drop, delivering approximately 60 blows per minute. A hammer of this size served very adequately for most pile driving (only when extremely long piles or when unusually high bearings were required were heavier hammers needed). It also had the added advantage from an inspection standpoint of providing for a positive check of the energy delivered by the hammer. To determine the actual energy output, in N·m (ft. lbs.), one merely multiplies the force of the ram times the height of the drop. If the drop could not be measured, "manufacturer's rated energy" at operating speed was used with a 25 percent reduction in bearing values, per Specification 2452.3.

For Double-Acting Steam or Air Driven Hammers (including Differential-Acting and Compound Hammers) the ram is raised by steam or compressed air, as it is in the case of single-acting hammers. In addition, however, the same source of power is utilized for imparting a force on the downstroke, thus accelerating the speed of the ram. This creates the same effect as would be obtained by a considerably longer stroke of a single-acting hammer where no force other than gravity is available for the down stroke.

Some double-acting hammers utilize a relatively light ram, operating at comparatively high frequencies, to develop energy blows comparable to those developed by considerable heavier, slower acting hammers. The advantage of higher frequencies is that less time is permitted for re-settling of the soils against the pile between blows, thus increasing driving efficiency and decreasing driving time. The disadvantage is that under some conditions considerable damage may be evidenced at the top of the pile, caused by high impact velocities. Therefore, the inspector should be particularly alert when a high velocity hammer is being used, since energy dissipated destroys a pile head. Only the energy which reaches the tip of the pile, or at the very least the center of resistance, is effective in producing additional penetration.

The energy delivered by double-acting hammers is generally related to frequency (strokes per unit of time), and is usually obtained by referring to hammer speed vs energy charts furnished by the manufacturer. Maximum rated energy probably never would be attained in actual practice. Therefore, if energy charts are not available, Mn/DOT Specifications provide for a 25 percent reduction of the maximum rated energy.

Diesel hammers are the most common type of hammer currently used in Minnesota bridge construction. They consist of a cylinder containing a ram and an anvil. The ram is raised initially by an outside power source (crane) and dropped as a drop hammer. As the ram drops, it actuates a fuel pump which injects fuel into the chamber or the anvil cup depending upon the make of the hammer. The heat of compression, or atomization by impact, ignites the fuel, expands the gases and forces the ram upward.

Three makes of diesel hammers have been used considerably on pile driving in Minnesota. These are the Delmag, the MKT and the ICE (originally introduced as the Syntron, then as a Link-Belt). The Delmag and the MKT hammers operate similarly in that the ram is raised by the explosion to a height that is determined by the energy produced by the explosion and then dropped freely as a single-acting hammer. In the case of the ICE hammer, the ram raises against an air cushion in an upper chamber which is enclosed, compressing the air in that chamber. The compressed air, when the ram has reached its maximum height, starts the ram downward with added momentum, somewhat like a double-acting hammer.

There are other variations in the operation of diesel hammers which affect their performance but which are considered to be beyond the scope of the general informational coverage of this manual. Additional information on operation and calibration of pile hammers can be found in "The Pile Inspector's Guide to Hammers" published by the Deep Foundation Institute. Pile hammer manufacturers are usually quite accommodating about furnishing brochures on their equipment upon request.

The energy delivered by diesel powered hammers is perhaps more variable and more dependent upon the resistance offered by the soils than is the case for other hammer types. Sudden energy surges develop whenever areas of high resistance to driving are encountered whereas areas of low resistance may cause malfunction by insufficient internal pressure to set off an explosion. The MKT company claims only the energy developed by the falling ram (WxH), whereas the Delmag Company also includes energy imparted by the explosion. Since the compression of the air by the ram tends to cushion the blow, Mn/DOT has selected the more conservative approach (WxH) as the most logical.

The ICE Series include a gauge which measures back-pressure and from which energy output can be determined. If no gauges or other measuring devices are provided, the inspector should use a saximeter (see the end of section 5-393.161 for more information on the saximeter) or stop watch and the formula indicated in 5-393.161, or as a last resort, manufacturers' rated energy at operating speed reduced by 25 percent for use in the dynamic bearing formula.

Vibratory and Sonic Power-Driven Hammers are the most recent developments in pile driving hammers. They are comparatively heavy, requiring handling equipment of greater capacity than required for conventional pile hammers.

The two types (vibratory and sonic) are not synonymous, as sometimes believed. The vibratory hammer, as the term implies, vibrates the pile at frequencies and amplitudes which tend to break the bond between the pile surfaces and the adjacent soils, thus delivering more of the developed energy to the tip of the pile. The sonic hammer operates at higher frequencies than does the vibratory hammer, usually between 80 and 150 cycles per second, and is tuned to the natural resonant frequency of the pile. At this frequency the pile changes minutely in dimension and length with each cycle, thus alternately enlarging the cavity and then shortening the pile.

Bearing values for these hammers would have to be determined by pile load tests. Current Specifications and pile driving formulas do not apply to these hammers.

Pile hammer leads serve to contain the pile hammer and to direct its alignment so that the force of the blows delivered by the ram will be axial to the pile. They also provide a means for bracing long, slender piles until they have been driven to sufficient penetration to develop their own support. It is, therefore, essential that leads be well constructed and that they provide for free movement of the hammer but not to the extent that they permit noticeable changes in hammer alignment.

For drop hammers it is especially important that the leads be straight and true, and that freedom of fall is unincumbered. If there are any bends or other restrictions to free fall, they would tend to reduce the acceleration of the hammer and consequently the energy delivered. Timber leads should be steel shod and drop hammer leads should be greased to reduce friction.

Three basic types of leads are described in Figure A 5-393.157; of these, the swinging leads are most common on Mn/DOT projects.

Bases, Anvil Blocks, Driving Caps, Adapters and Shock Blocks are accessories which are required in varying combinations and types, depending upon the type, make and model of hammer and upon the type and size of the piles being driven. The best assurance that the proper types and combinations are being used is to follow the recommendations of the pile hammer manufacturer as given in their brochures or catalogues.

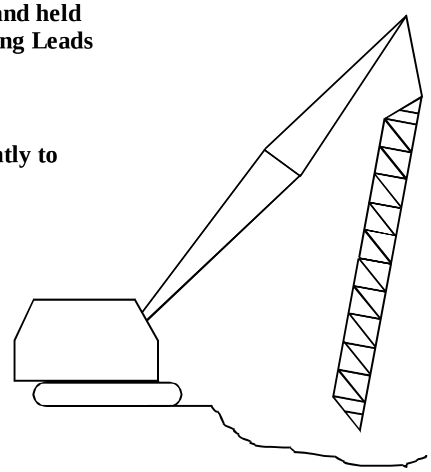
These items protect the pile and the hammer against destructive impact and keep the pile head properly positioned with the leads. Shock blocks are required particularly when driving precast concrete piles, since the impact would otherwise shatter the comparatively brittle concrete. Also, the proper arrangement and combination of these accessories will tend to distribute the impact more uniformly over the top surface of the pile, thus protecting it against eccentric blows which might otherwise cause failure of the butt of the pile before required penetration and bearing is obtained. Excessive thickness of shock block material, particularly soft wood or spongy material will reduce the energy delivered to the top of the pile and should be avoided.

Except for self-contained power source hammers such as diesels, vibratory and sonic hammers, an outside power source is required for power-driven hammers. Not long ago steam boilers were used exclusively for developing power; however, currently boilers have been replaced by air compressors.

Regardless of the source, adequate power must be supplied if the hammer is to function properly. When an adequate power source is not supplied, continuous driving will deplete the supply to the extent that malfunction will generally result. This usually means that the hammer will operate at something less than specified stroke or frequency, or both, or that it will cease operating entirely until sufficient power build-up has been attained.

SWINGING LEAD

This Lead is hung from a Crane Boom with a single line. In use, this Lead is spotted on the ground at the Pile location, generally with Stabbing Points attached, and held Plumb or at the desired Batter with the supporting Crane Line. Short swinging Leads are often used to assist in driving Steel Sheet Piling.



ADVANTAGES

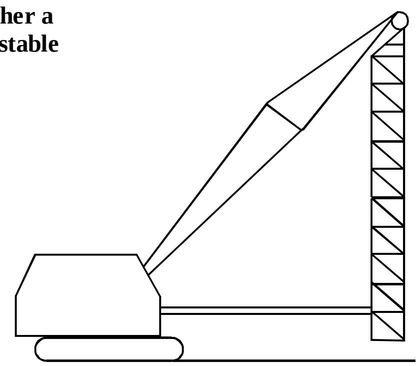
- Lightest, simplest and least expensive.
- With Stabbing Points secured in ground this Lead is free to rotate sufficiently to align Hammer with Pile without precise alignment of Crane with Pile.
- Because these Leads are generally 4-6 m (13-20 feet) shorter than Boom, Crane can reach out farther, assuming the Crane capacity is sufficient.
- Can drive in a hole or ditch or over the edge of an excavation.
- For long Lead and Boom requirements, the Lead weight can be supported on the ground while the Pile is lifted into place without excessively increasing the working load.

DISADVANTAGES

- Requires 3-Drum Crane (1 for Lead, 1 for Hammer, and 1 for Pile) or 2-Drum Crane with Lead hung on Sling from Boom Point.
- Because of Crane Line Suspension, precise positioning of the Lead with Pile Head is difficult and slow.
- Difficult to control twisting of Lead if Stabbing Points are not secured to ground. It is more difficult to position Crane with these Leads than with any other. You must rely on balance while center of gravity continues to move.

UNDERHUNG LEAD

This Lead is pinned to the Boom Point and connected to the Crane Cab by either a Rigid Bottom Brace for vertical driving or a Manually or Hydraulically Adjustable Bottom Brace for Fore and Aft driving.



ADVANTAGES

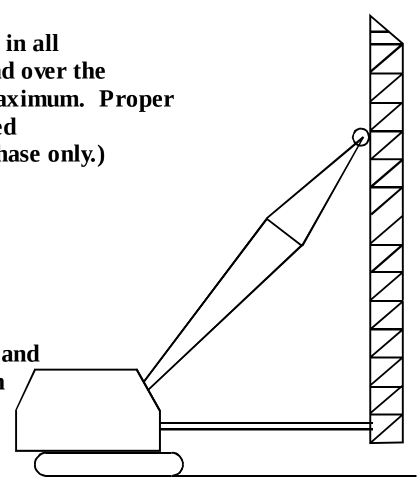
- Lighter and generally less expensive than extended type Lead.
- Requires only 2-Drum Crane.
- Accuracy in locating Lead in Vertical or Fore and Aft Batter positions.
- Rigid control of Lead during positioning operation.
- Reduces rigging time in setting up and breaking down.
- Utilizes Sheave Head in Crane Boom.

DISADVANTAGES

- Cannot be used for Side to Side Batter Driving, requires precise alignment of crane with the piling.
- Length of Pile limited by Boom length since this type of Lead cannot be extended above the Boom Point.
- When long Leads dictate the use of a long Boom, the working radius which results may be excessive for the capacity of the Crane.
- Does not allow the use of a Boom shorter than the Lead.

EXTENDED 4-WAY LEAD

This Lead attaches to the Boom Point with a swivel connection to allow Batter in all directions when used with a a Parallelogram Bottom Brace. Extension of Lead over the Boom Point must not exceed L/3 of total Lead length or up to 8 m (25 feet) maximum. Proper selection of components will provide a Lead which can be accurately positioned hydraulically or manually and which can be remotely controlled (Hydraulic Phase only.)



ADVANTAGES

- Requires only 2-Drum Crane
- Accuracy in locating Lead in Vertical Position and all Batter Positions.
- Rigid control of Lead during positioning operation.
- Compound Batter angles can be set and accurately maintained.
- Allows use of short Boom with resulting increase in capacity
- Boom can be lowered and Leads folded under (for short-haul over the road and railroad travel) when Crane of adequate capacity is used. (This depends on the length of Lead and Boom and the configuration of the Crane.)

DISADVANTAGES

- Heaviest and most expensive of the three basic Lead types.
- More troublesome to assemble.

5-393.158 INSPECTION OF PILE DRIVING - TIMBER PILES

As previously mentioned in 5-393.151, pile driving inspection is a very important function and is deserving of undivided attention. Some agencies specializing in piling go so far as to recommend that a trained soils engineer be present to approve each pile installation and to revise procedures as varying soil conditions are encountered. Certainly the inspector should have sufficient knowledge of soil types and characteristics so as to be able to relate the soils information shown on the survey sheet to the pile driving operations and difficulties.

The inspector should be present at all times when piles are being driven. This is particularly true when driving timber piles because breakage below the ground surface may occur at any time and may be detected only by an alert inspector. It would also be true of any piles driven through or into hard strata, such as rock or hardpan, since the tips may be damaged by over-driving or carelessness unless a capable inspector is present.

Treated timber piles are generally inspected for quality and treatment prior to delivery, and are impression-stamped so that the pile driving inspector will know that they have been inspected and approved. Occasionally a slightly under-size pile may get by the plant inspector. Specification 1503 states "all materials furnished shall be in conformance with the lines, grades, cross sections, dimensions, and material requirements, including tolerances, shown in the Plans indicated in the Specifications". This gives the Engineer authority to use some discretion regarding acceptance of occasional borderline or slightly undersize piles. Piles which are slightly out of specifications for crooks or twists should be called to the attention of the foreman and accepted only if they can be satisfactorily driven without splitting or breaking.

Untreated timber piles, except for treatment, are subject to the same inspection as are treated piles. However, these piles are often delivered to the jobsite without previous inspection; if so, complete inspection for type, quality, straightness, knots, peeling, density, and butt and tip diameters must be made at the site and reported on Form 2415. See Specification 3471.

It is very important that timber piles in a bent be accurately located and properly driven, because little can be done to correct their alignment after driving without causing damage to the piles. The best procedure to assure accurate alignment is to drive the end piles for each bent first, using piles with the largest diameters, and then placing a heavy timber on each side long enough to extend beyond each end pile. These timbers should be tied to each other using bolts or scabs. The remaining piles in the bent can then be spotted and driven within this yoke or frame, which will assist in maintaining their alignment. A hole should be dug for each pile as a means of getting it started properly. Each pile should be observed very closely while it is being driven, to assure plumbness or specified batter. Also, when driving is hard, check closely for evidence of cracking, breaking or splitting, so that driving can be stopped before the pile is severely damaged.

The test pile for each unit is generally placed at one end so that the original pile number and spacing can be changed, if necessary to support the superimposed load. After the first unit has been driven, blocking can be used between this unit and the timber guides for the next unit.

Extra care taken during the pile driving, with respect to the proper location of each pile, will minimize the problems encountered in placing the caps, bracing or backing. This is especially true with regard to the corner piles at abutments.

Timber piles which do not line up properly after driving should be brought to line before making the cut-off, so that the top of the pile, after cut-off will be at correct elevation and plane and will provide full bearing for the pile cap. Wooden straight edges should be placed on each side of the pile bent to act as a guide for the saw, and the actual sawing should be done by experienced sawyers. Power saws are extremely difficult to control to the degree required for this type of work and should not be used except when the Contractor has demonstrated that the proper degree of accuracy can be obtained.

Any portion of the top of the timber pile which projects outside of the front edge of the wing cap should be trimmed off with a sharp axe or adz in a neat manner to an approximate 45 degree slope down and outward from the front edge of the wing cap.

Specifications (2452.3F) provide timber pile top cutoff requirements. Read these Specifications carefully, and use the method specified for the particular location. Regardless of the method used, the workmanship should be neat and systematic.

Where zinc sheets are specified in the plans or special provisions for the tops of timber piles, the portion of the sheet which extends outside of the periphery of the pile should be folded down alongside the pile. The folds should then be creased and folded back against the pile. The folds should then be securely fastened to the pile with galvanized roofing nails. Rounding off the corners of a square sheet before placing will produce neater results than would otherwise be obtained. Fabric protection can be placed in much the same manner as described above for zinc sheets. Treatment of tops of timber piles with preservative is required prior to placement of zinc sheeting.

5-393.159 INSPECTION OF PILE DRIVING - STEEL PILES

Steel pile is not inspected prior to delivery to the jobsite. Therefore, pile inspection must be performed by the project inspector. For Steel H-Piles and Steel Shells for Cast-In-Place Concrete piles, Specifications 3371 and 3372 require the Contractor to submit three copies of mill shipping papers and certified mill test reports for all steel piling prior to delivery of piling to the site. These mill test reports are provided by the producer steel mill and list physical properties and chemical analysis of each mill “heat” of steel involved, and specify domestic origin of steel and its manufacture. The contractor is responsible to verify that invoices and mill test reports correspond to piling delivered. Upon delivery, spot check identification markings on the steel to be certain the source and heat numbers match those on the mill test reports. At the same time, inspect the material for proper section size and gauge, physical defects such as kinks or buckles, and quality of welding.

If any piece of piling is not marked with a heat number, the Project Engineer should have the Contractor test the material at an independent testing lab to ensure the pieces are associated with the mill test reports provided. Two tensile tests and one chemistry test should be conducted from one out of ten pieces of piling of the same size and thickness with unknown identity. Piles that are driven prior to material testing should be identified in the “Pile Driving Report”. Price adjustments or other determination can then be made at a later date, should this be necessary because of the deficiencies in the material. In any event, contractors should be made aware that piles driven prior to delivery of required materials information are subject to price adjustment until quality and domestic origin has been properly established.

Welding for splices, except in isolated cases must be made by Mn/DOT certified welders. A typical exception might be when one or two unanticipated splices are necessary and a certified welder is not immediately available, but a reputable uncertified welder is available. Keep in mind that this should be interpreted as applying only to exceptional and isolated cases, and should not be general practice. See Section 5-393.155 for information regarding welding and welder certification.

When trestle piles or pile bents are involved, painting requirements should be reviewed. Generally a complete prime coat is required for the full length of steel piles which extend above ground except for those sections below splices which are at least 600 mm (2 feet) below ground.

Holes for handling steel H-piles should not be made in the flanges of the piles, except when they are made near the top of the pile and are to be included in the cut-off portion or in the portion which will be embedded in the concrete. Burning holes with a torch should not be permitted, even in the web of the pile, because of carelessness generally associated with the torch. It has been agreed, in a discussion with representatives of the Federal Highway Administration, that holes may be drilled in the webs near the longitudinal centerline of the pile, but that these holes should be no larger than necessary to accommodate the connector used for lifting the pile.

In any event, caution must be observed when using holes in steel piles for handling purposes. Sharp or jagged edges may cut or fray the lifting cable, and thereby weaken it possibly causing premature failure. Although it is the Contractor’s responsibility to conduct his/her work in a safe manner, an alert inspector should report unsafe conditions to the foreman as well as to the Engineer in charge. Pile driving is an inherently dangerous operation, but precautionary measures can be done to improve conditions.

5-393.160 PILE DRIVING FORMULAS

Several methods have been developed to allow inspectors in the field to determine the capacity of a driven pile. One of the simplest methods allows the inspector to record certain pieces of data during pile driving (blows per foot (penetration), and energy) and by inputting this data into a mathematical formula, the pile capacity can be determined. This type of formula is often referred to as a "dynamic" pile formula because it converts the data from a dynamic process (pile driving) into a static force (the pile capacity or resistance).

Different dynamic pile formulas are required, depending on the method used to design the bridge foundations. Prior to 2005 most bridge foundations in Minnesota were designed using the Allowable Stress Design (ASD) method. Starting in late 2005 the Load and Resistance Factor Design (LRFD) method was implemented for the design of foundations for most new trunk highway bridges. However, most non-trunk highway (county, city, township, etc.) bridges continue to be designed using the ASD method.

The differences between these design methods can be explained as follows:

The ASD method involves determining the load capacity for a given pile and reducing it by a safety factor to get what is called the allowable pile load. Then the design loads affecting the pile such as the weight of the concrete it supports, earth loads, traffic, etc. are added together, resulting in what is called the actual pile load. The actual pile load must be less than the allowable pile load in order for the design to be adequate. Some shortcomings of this method are:

- The safety factor is only applied to the capacity and not the load. ASD does not consider the fact different loads have different levels of uncertainty.
- Selection of the safety factor is subjective, and does not consider the statistical probability of failure. This means that there is not a uniform level of safety for all designs.

When the ASD method is used, the bridge plan includes one pile load table for each substructure unit and the minimum load that piling should be driven to in the field is referred to as the “Design Load” in the table, see Figure A 5-393.160 for an example.

COMPUTED PILE LOADS - TONS/PILE	
D.L. & EARTH PRESSURE	40.1
LIVE LOAD	6.2
OVERTURNING	15.5
* DESIGN LOAD	61.8

$* \frac{61.8}{1.25}$ = 49.5 REDUCTION AS PER AASHTO 3.22.1 GROUP III LOADING

FIGURE A 5-393.160

The LRFD method includes a safety factor on the loads applied to the pile and to the resistance of the pile. The safety factor applied to the load is called the load factor and increases the load based on the uncertainty of its magnitude. The safety factor applied to the resistance of a pile is called the resistance factor and reduces the resistance based on the uncertainty of its magnitude. The values used for the load and resistance factors are based on the statistical probability of failure and therefore provide a more uniform level of safety than the ASD method.

For LRFD, the factored load must be less than the factored nominal pile bearing resistance in order for the pile design to be adequate. When the LRFD method is used, the bridge plans will include two pile load tables for each substructure unit. The first table will report the factored pile loads and the second table will report the load for driving, R_n. See Figure B 5-393.160 for an example.

PIER COMPUTED PILE LOAD – TONS/PILE	
FACTORED DEAD LOAD	84.0
FACTORED LIVE LOAD	36.0
FACTORED OVERTURNING	0.0
* FACTORED DESIGN LOAD	120.0

* BASED ON STRENGTH I LOAD COMBINATION

PIER REQUIRED NOMINAL PILE BEARING RESISTANCE R_n TONS/PILE		
FIELD CONTROL METHOD	Φ_{dyn}	* R_n
Mn/DOT NOMINAL RESISTANCE FORMULA	0.4	300.0
PDA	0.6	200.0

* R_n = FACTORED DESIGN LOAD / Φ_{dyn}

FIGURE B – 5-393.160

The inspector in the field will need to know which design methodology (ASD or LRFD) was used to design the bridge foundations, because each method uses a different dynamic formula to compute the pile capacity in the field. There are several ways to determine which design method was used on a particular bridge. The simplest is to review the "Construction Notes" on the first sheet of the bridge plans (this sheet shows the general plan and elevation of the bridge). If the foundations were designed using LRFD methodology the following note will appear "The pile load shown in the plans and the corresponding bearing capacity (R_n) was computed using LRFD methodology. Nominal pile bearing resistance determination in the field shall incorporate the methods and/or formulas described in the Special Provisions." The special provisions will include the nominal pile bearing resistance equation discussed in section 5-393.160B below. If the "Construction Notes" do not include the statements mentioned above, then the foundation was designed using the ASD methodology and the inspector should use the dynamic formulas discussed in section 5-393.160A below.

An alternative method to determine if the LRFD design methodology was used for the foundation design is to review the pile load tables shown in the bridge plans (the pile load table indicates the bearing resistance that the piles need to be driven to to support the structure). If the pile load tables are similar to that shown in Figure B 5-393.160, with a statement in the bottom table indicating "Required Nominal Pile Bearing Resistance R_n" then the foundation was designed using the LRFD design methodology and the special provisions will include the equation discussed in section 5-393.160B. If only one pile load table is shown for each substructure, and if it looks similar to that shown in Figure A 5-393.160 and it does not include the terminology "Required Nominal Pile Bearing Resistance R_n", then the inspector can assume that the foundation was designed using ASD methods and the dynamic formulas discussed in 5-393.160A should be used to determine the pile capacity in the field.

A very significant difference between the two methods is the magnitude of the computed loads. Generally speaking, the loads computed using LFRD methodology will be approximately 3.0 - 3.5 times higher than loads computed using ASD methods. To better illustrate this, the table below indicates a range of "normal" capacities for several types of pile using each design method.

Pile Type	ASD Load Range	LRFD R_n Load Range
12" CIP (0.25" Wall thickness)	60-75 tons	210 - 250 tons
HP 10 x 42	60-75 tons	210 - 275 tons

Because of the differences in the magnitude of the loads, the importance of using the correct dynamic formula in the field cannot be overstated. If you review the bridge plan for a particular project using the criteria and information provided above and are still not sure which design method was used, do not hesitate to call the Bridge Construction Unit for further assistance. Using the wrong dynamic formula to determine pile capacity in the field can result in the construction of an unsafe foundation. It is incumbent upon the inspector to be 100% sure that the correct dynamic formula is being used.

Also, the inspector should always read the special provisions carefully, since in some cases the use of the pile driving analyzer may be required. Refer to section 5-393.166 of this manual for more information on the pile driving analyzer.

A. Dynamic Formulas Used With Allowable Stress Design (ASD)

Dynamic pile driving formulas provide a means of converting resistance to a dynamic force to resistance to static force. Many variations of dynamic formulas are currently in use throughout the country, and most of them include the following factors: (1)

the energy in Newton-meters (foot-pounds) delivered by the hammer, (2) the losses sustained through temporary compression of all parts below the top of the anvil including the soil surrounding the pile, (3) the resistance to penetration offered by the soils.

The resistance offered by the soils while being disturbed by vibrations and displacement may be quite different than that which will subsequently be offered against long-time static loads. Some soils will readjust subsequent after completion of driving, so that the high resistance during driving may be only temporary. It is claimed by Chellis in his book on Pile Foundations that it has been reported that piles driven in saturated coarse-grained cohesionless soils have shown up to 50 percent decrease in resistance to driving during the first 24 hours after initial driving. Dynamic formulas can be used safely only when redriving results after rest are not significantly less than the results from the final original driving. In plastic soils, the resistance to driving will likely increase after a delay, but resistance may not increase significantly for granular soils. Therefore, it is prudent not to place too much reliance on anticipated build-up of driving resistance during a delay period.

The most simple of all dynamic pile driving formulas is the one commonly known as the Engineering News Formula. This formula does not take into account the mass that must be set in motion by the ram, this assumes the loss to be constant regardless of the mass. Therefore, many states, including Minnesota, have adopted other formulas which do consider this, as well as other factors. This is not to say that we believe our formulas to be the final answer; as a matter of fact, it is fully recognized that even formulas that are considerably more sophisticated than those appearing in MnDOT Specifications still do not account for all of the variables in a pile driving system.

The original Engineering News formula was developed to be used for pile driving with drop hammers, in the following form:

Where

$$R = \frac{2F}{S + 1.0}$$

R = resistance
F = foot-pounds of force or energy imparted by the hammer
S = set, or penetration in inches per blow
1.0 = assumed losses sustained due to temporary compression in the pile cap, cushion, pile, and in the soil system.

Since F is equal to WxH (weight of hammer in pounds times height of drop in feet) and S is measured in inches, it becomes necessary to reduce F to inch-pounds by multiplying F by 12. However, in order to account for all losses except temporary compression losses, as well as to provide some factor of safety, 2F is used arbitrarily instead of 12F, thereby introducing a "reduction factor" of 6.

Some variations in the above formulas have been used for power-driven hammers, but the reduction factors have been arbitrary and without consideration for the weight being driven or the response of different pile materials and types to driving.

The original Mn/DOT formulas were adopted shortly after WWII as a means of introducing certain variables which have an influence on driving results, and which are accounted for only arbitrarily by a constant "reduction factor" in the Engineering News Formulas.

For gravity (drop) hammers the following english form is used:

$$P = \frac{3\,WH}{S + 0.5} \times \frac{W + 0.1\,M}{W + M}$$

For power-driven hammers with timber, concrete, and shell type piles, the following english form is used:

$$P = \frac{3.5\,E}{S + 0.2} \times \frac{W + 0.1\,M}{W + M}$$

Where:

P = Safe bearing capacity (resistance) in pounds
W = Weight of striking part (ram) in pounds
H = Height of fall in feet
E = WxH for single acting power-driven hammers; it also equals the foot pounds of energy per blow for each full stroke of either single acting or double acting hammers as given by the manufacturer's rating for the speed at which the hammer operates.
S = Average penetration per blow (set) in inches per blow for the last 5 blows for gravity (drop) hammers and for the last 10 or 20 blows for power-driven hammers, except in cases where the pile may be damaged by this number of blows.
M = Total weight of pile and driving cap
0.5, 0.2 = Assumed losses sustained due to temporary compression in the pile cap, cushion, pile and in the soil system.

For gravity dropped hammers the energy (WxH) was determined as follows: since H is given in feet and S is in inches, it becomes necessary to introduce 12 as a numerator in the first term. The first term thus becomes

$$\frac{12WH}{S + 0.5}.$$

It is recognized that losses sustained in a drop hammer due to line drag, friction against the leads and other factors, tend to reduce efficiency to approximately 75 percent. Therefore, 12WH becomes 9WH. Also, since it is desirable to provide a built-in safety factor of 3, 9WH becomes 3WH. For power-driven hammers the equation assumes more energy and less assumed losses.

The W-M relationship in the second term, $\frac{W + 0.1M}{W + M}$

recognizes that the damping effect on energy delivered by the hammer is related to the mass to be set in motion; that is, the larger the pile mass, the greater the damping effect, and the greater the reduction in energy delivered to the point of the pile to do the work. The effect of this term can readily be determined by referring to the pile bearing tables included in this section of the manual, and noting the reduction in bearings as you read from low to high pile weights at constant penetration per blow.

An additional refinement using 0.2 instead of 0.1 in the second term numerator accounts for cushioning effect losses at impact, and recognizes that steel H-piles consume less impact energy through cushioning than do other types, particularly when driven with power-driven hammers and when using only steel shock blocks or caps.

For gravity (drop) hammers the following form for metric bearing capacity is used:

$$P = \frac{2.5\,WH}{S + 13} \times \frac{W + 0.1\,M}{W + M}$$

For power-driven hammers with timber, concrete, and shell type piles, the following metric form is used:

$$P = \frac{289\,E}{S + 5} \times \frac{W + 0.1\,M}{W + M}$$

Where:

P =Safe bearing capacity (resistance) in N
W =Mass of striking part (ram) in kg
H =Height of fall in mm
E =WxHx0.00981 for single acting power-driven hammers. It is equal to the joules or newton-meters of energy per blow for each full stroke of either single acting or double acting hammers as given by the manufacturer's rating for the speed at which the hammer operates.
S =Average penetration per blow (set) in mm for last 5 blows for gravity (drop) hammers and for the last 10 or 20 blows for power-driven hammers, except in cases where the pile may be damaged by this number of loads.
M =Total mass of pile and driving cap in kg
13, 5 =Assumed losses sustained due to temporary compression in the pile cap, cushion, pile and in the soil system.

Again, however, the static resistance at the time of driving does not necessarily reflect the true resistance to long time loads, or to soil set-up due to consolidation.

B. Dynamic Formulas Used With Load and Resistance Factor Design (LRFD)

For foundations designed using LRFD methodology the nominal pile bearing resistance determination in the field can be determined by using yet another dynamic formula or by using the Pile Driving Analyzer (PDA). Section 5-393.166 provides further information on the pile driving analyzer.

To determine the nominal pile bearing resistance of driven piles Mn/DOT uses the following single formula for timber, concrete, steel H-piling, and shell type piles, all driven with power-driven hammers:

$$R_n\text{ (metric)} = \frac{867E}{S + 5} \times \frac{W + 0.1M}{W + M}$$

$$R_n\text{ (english)} = \frac{10.5E}{S + 0.2} \times \frac{W + 0.1M}{W + M}$$

Where:

R_n =Nominal pile bearing resistance in Newtons (**pounds**).
W =Mass of the striking part of the hammer in kilograms (**pounds**).
H =Height of fall in millimeters (**feet**).
S =Average penetration in millimeters (**inches**) per blow for the last 10 or 20 blows, except in cases where the pile may be damaged by this number of blows.
M =Total mass of pile plus mass of the driving cap in kilograms (**pounds**).

*The following definition is for Metric units, see English units below:

E =WHx0.00981 for single acting power-driven hammers. It is equal to the joules or newton-meters (joule = newton-meter) of energy per blow for each full stroke of either single acting or double acting hammers as given by the manufacturer's rating for the speed at which the hammer operates.

*The following definition is for English units:

E =WH for single acting power-driven hammers. It is equal to the foot pounds of energy per blow for each full stroke of either single acting or double acting hammers as given by the manufacturer's rating for the speed at which the hammer operates.

C. Dynamic Formulas – Notes

Regardless of which formula is used, when provisions are not made available for field determination of the energy output on a power-driven hammer, such as measurement of the drop for single-acting hammers, or such as pressure gauges or determination of energy on the basis of the frequency of the blows (cycles per minute) for double-acting hammers, the manufacturer's rated energy shall be reduced by 25 percent. This reduction is not intended to apply when determining the required hammer size (when qualifying a pile hammer). Double-acting hammers, for the purpose of these requirements, will include all hammers for which a power source is utilized for acceleration of the down-stroke of the ram. The dynamic formulas discussed previously are only applicable when:

(a) The hammer (ram) has a free fall.
(b) The head of the pile is free from broomed or crushed fibre.
(c) The penetration of the pile is at a reasonably uniform rate.
(d) There is not noticeable bounce after the blow. When there is a noticeable bounce, twice the bounce height shall be deducted from H to determine the value of H in the formula.

The information recorded in the field by the inspector is the same no matter what Mn/DOT dynamic formula is used. So regardless of whether the bridge was designed using the ASD or LRFD methodology, the inspector records the same data during pile driving, but inputs the data into the appropriate formula, depending on the method used to design the foundation.

5-393.161 INSPECTION OF PILE DRIVING – EQUIPMENT

The pile hammer to be used for driving test piles, foundation piles, and trestle piles must meet certain minimum specification requirements for mass of ram and rated energy. In addition to these requirements, or in lieu of them, special requirements are sometimes written into the Special Provisions for the job. This helps to assure that adequate penetration and/or bearing capacity will be obtained. Design pile loads, especially for steel H-piles and for cast-in-place concrete piles, have been increased substantially in recent years, thereby creating an ever increasing demand for larger and better pile driving equipment.

After thoroughly understanding the pile hammer requirements, the inspector in charge should discuss them with the Contractor. This may save time and embarrassment later, in the event of misinterpretation by either party, especially if the Contractor had been considering the use of a pile hammer which did not meet all of the requirements. Pile hammers which are at considerable variance with each other with respect to mass, energy rating, and frequency, may also produce variance in results.

The inspector should determine whether or not the driving cap to be used is suited for the type and size of pile to be driven. An improper cap may cause damage to the top of the pile, thus resulting in substantial loss of driving energy to the pile. This will result in a false resistance value, as well as undue waste of piling and excessive driving time. The importance of providing a pile cap which fits properly on the top of the pile can perhaps be better understood if you will visualize what might happen if the cap were removed and the ram were permitted to strike one edge or one corner of the pile. The same results could occur without the proper cap. In both cases the pile butt could be damaged, even without encountering high resistance. Some driving caps have provisions for cushion blocks, generally of hard wood or soft metal, to avoid excessive impact on the steel block and on the pile head.

Pile caps for timber piles should be recessed so as to receive the pile head, which in turn should be trimmed to fit snugly into the recess. This offers protection against splitting and brooming, particularly when hard driving is encountered.

The auger used for preboring holes through embankments, or through or into dense soils to obtain additional penetration should be checked for diameter dimension. Make certain that the prebored hole will be larger than the maximum diameter of the piles to be driven.

A. Hammer Qualification

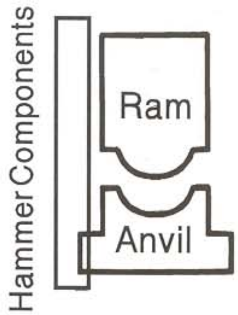
Inquire as soon as possible as to the make and model of the pile hammer the Contractor proposes to use for the job. It is then advisable to determine immediately whether or not that hammer will be adequate for the pile weight to be driven and for the bearing required. Read the special provisions and Specification 2452.3C carefully as it applies to Equipment for Driving and for Penetration and Bearing.

The special provisions will provide information regarding the method to be used to qualify a pile hammer if the LRFD design methodology (see section 5-393.160 of this manual) was used to design the piling. Generally speaking for LRFD designs, the contractor will be required to have a wave equation analysis completed. The wave equation is a recent development in determination of pile capacity that uses a one-dimensional wave equation computer program. After inputting pertinent information about the pile driving system and the soil types at the proposed site, the program uses a complicated mathematical model to predict the following information for one blow of the ram for the specified soil resistance; (1) stresses in the pile, (2) displacement of the pile (penetration), (3) static nominal load resistance of the pile for a specified resistance and distribution. The proposed pile driving system is analyzed to ensure that minimum bearing values can be achieved without over stressing the piling. Figure A 5-393.161 provides an example of a Pile and Driving Equipment Data Form that is used to collect information needed to perform a wave equation analysis. Review the project special provisions for complete details on the criteria and requirements that must be satisfied as part of the wave equation analysis.

Figure A 5-393.161
Pile and Driving Equipment Data Form

Contract No.: ____________________
Project: ____________________
____
County: ____________________

Structure Name and/or No.: ____________________
____
Pile Driving Contractor or Subcontractor: ____________________
____
(Piles driven by)



Hammer

Manufacturer: ____________ Model No.: ____________
Hammer Type: ____________ Serial No.: ____________
Manufacturers Maximum Rated Energy: ____________ (ft-lbs)
Stroke at Maximum Rated Energy: ____________ (ft)
Range in Operating Energy: ____________ to ____________ (ft-lbs)
Range in Operating Stroke: ____________ to ____________ (ft)
Ram Weight: ____________ (lbs)
Modifications: ____________
____
____

Striker Plate

Weight: ____________ (lbs) Diameter: ____________ (in)
Thickness: ____________ (in)

Hammer Cushion

Material #1
Name: ____________
Area: ____________ (in²)
Thickness/Plate: ____________ (in)
No. of Plates: ____________

Material #2
(for Composite Cushion)
Name: ____________
Area: ____________ (in²)
Thickness/Plate: ____________ (in)
No. of Plates: ____________

Total Thickness of Hammer Cushion: ____________

Helmet (Drive Head)

Weight: ____________ (lbs)

Pile Cushion

Material: ____________
Area: ____________ (in²) Thickness/Sheet: ____________ (in)
No. of Sheets: ____________
Total Thickness of Pile Cushion: ____________ (in)

Pile

Pile Type: ____________
Wall Thickness: ____________ (in) Taper: ____________
Cross Sectional Area: ____________ (in²) Weight/Meter: ____________

Ordered Length: ____________ (ft)
Design Load: ____________ (kips)
Nominal Pile Bearing Resistance: ____________ (kips)

Description of Splice: ____________
____
Driving Shoe/Closure Plate Description: ____________
____
Submitted By: ____________ Date: ____________
Telephone No.: ____________ Fax No.: ____________

For foundations designed using Allowable Service Design (see section 5-393.160 of this manual) the inspector should enter the pertinent information into the appropriate formula given under Determination of Bearing Capacity and determine whether or not the required bearing can be obtained at a penetration per blow that is not less than substantial refusal. Maximum rated energies for a number of commonly used pile hammers are listed in Table A 5-393.164. Physical properties of timber pile, steel shells, and H-pile are listed in Tables B-F 5-393.164.

Example:

The plans indicate that the piling were designed using the Allowable Stress Design (ASD) method. Review of the special provisions and specifications indicate that power driven hammers are required to yield a computed bearing of 130 percent (may be 160 percent in some cases, refer to the special provisions) of the design load at a penetration of not less than 1.3 mm (0.05 inch) per blow.

Say Design Load	= 100 ton
1.30 x 100	= 130 ton
Single-Acting Diesel Hammer	
Max. Energy Rating	= 43,200 ft. lbs.

Note that no energy reduction is applied in the determination of adequacy of the hammer. (Don't apply a 25% reduction in energy for unknown stroke).

Pile Mass (16" CIP 42.05 lbs @ 50')	= 2102.5 lbs
Cap Mass	= 2150 lbs
M	= 4252.5 lbs
Ram Mass (W)	= 4190 lbs

$$P = \frac{(3.5 \text{ x } 43200)}{(0.05 + .2)} \text{ x } \frac{(4190 + (0.2 \text{ x } 4252.5))}{(4190 + 4252.5)}$$

P = (604800) x (.5970)
P = 361066 (÷ 2000)
P = 180 ton

Therefore, the proposed hammer greatly exceeds the 130 ton requirements. If, however, the design load were 150 ton, the required bearing for substantial refusal would be 1.30 x 150 ton = 195 ton. Then, the proposed hammer would not qualify and a larger hammer would have to be furnished.

The Specifications regarding pile hammers may vary somewhat from one edition of the Standard Specification book to the next, or even for different jobs under the same Standard Specifications. In addition, the inspector should always check the Special Provisions as well as Standard Specifications. Remember that the Special Provisions govern over the Standard Specifications.

Although the Specifications have placed no upper limit on the size of hammer that may be used for pile driving, good judgment will dictate that every type and size of pile will have a limit as to the amount of energy that it can absorb without becoming excessively damaged. Timber and precast concrete piles are the most susceptible, particularly when timber quality and size is marginal, or when driving is difficult. It would be advisable to try to discourage the Contractor from using a hammer with a ram mass greater than about 2200 kg (4850 lbs.) for timber piles. The inspector should consult with the Contractor and the Engineer whenever it becomes apparent that the hammer being used on the job is too large for the piles being driven, regardless of type or size.

B. Energy Determination

Perhaps one of the most baffling determinations an inspector encounters when making pile bearing computations is the determination of energy delivered by driving hammers. Keep in mind that the energy claimed by the manufacturer for power-driven hammers is almost always the maximum attainable under ideal conditions and with the pile at “refusal.” A “refusal” condition generally does not exist except when the tip of the pile is on rock. The following information is based on hammers which are functioning properly. If the hammer is malfunctioning, repairs should be made to restore it to proper operation or a replacement hammer is to be furnished by the Contractor. In no instance should driving be permitted with a hammer that is not functioning properly.

Some double-acting hammers are rated on the basis of the number of cycles per minute, and some on the amount of pressure developed in the top chamber as measured by a special gauge. When the hammer speed versus energy charts or special provisions are provided, then the energy developed can be determined during driving. If no means is provided for field determination of energy, then a 25 percent reduction should be applied to the bearing computations; except when it is known that the tip of the pile is on bed rock, in which case the full energy rating may be used. For double-acting hammers where energy ranges are given by the manufacturers, the lower limit should be used as the rated energy unless details are furnished which justify using a higher rating.

Single-acting power hammers are also rated by the manufacturer on the basis of maximum energy attainable. This is limited by the maximum length of stroke. The inspector should determine whether or not the maximum stroke is being obtained, and adjust the energy when it is not operating at the maximum stroke. This is particularly true of single-acting diesel hammers, where the stroke is dependent upon the force of the explosion, which is in turn dependent to some extent on the resistance being offered by the soils. Application of a 25 percent reduction may not be sufficient for these hammers. At times the length of the stroke may be only one-half of the maximum stroke and, therefore, a 50 percent reduction would be appropriate.

If the length of stroke cannot be measured, but the hammer is operating close to the maximum stroke, the "manufacturer's rated energy," may be used with a 25 percent reduction in bearing values.

Some single-acting diesel hammers have an "energy range" for manufacturers' rated energy. Where this occurs, the stroke should be determined by the stroke indicator rod. When there is no stroke indicator attached to the hammer (and no other method of measuring stroke can be devised), the stroke can be determined by the formula: Stroke (feet) = $0.04t^2 - 0.3$ where t is the time (in seconds) required for 11 hammer blows (10 strokes) under operating conditions. This formula assumes vertical operation of the hammer and must be modified if driving piles battered flatter than 3 in 12. The rated energy is then determined by the ratio of the measured stroke to the maximum stroke times the upper limit of the "energy range."

The saximeter is a hand-held unit which uses sound recognition to automatically detect hammer blows. Background noise is managed through manual or automatic adjustment of the sound level at which a blow is detected. When the pile has penetrated one depth increment (such as 1 foot) the operator presses a button. The saximeter then displays the blows per increment (blows per foot) and the average hammer stroke over the increment. This makes filling out test pile reports much simpler as the saximeter automatically determines the stroke, which can be converted to energy by multiplying by the ram weight, and it also provides the blows per foot.

Since the energy of drop hammers is determined by multiplying the weight of the ram (W) times the height of free-fall (H) times the acceleration of gravity. It may be necessary to reduce the energy if the fall is not completely "free," i.e., friction between the hammer and leads. See Section 5-393.157 for additional information on drop hammers.

5-393.162 INSPECTION OF PILE DRIVING - PROCESS

Before pile driving is started, the excavation should be substantially complete, at least to the extent that bearing values will not be adversely affected by material which will later be removed. Also, except for cofferdams which are to be sealed with concrete, water within the excavation should be pumped out to the extent that pile placement and hammer operation will not be impaired. Underwater driving requires a "closed" hammer, with a rod attachment for penetration measurements. Punches or chasers are not permitted under any circumstances.

Study the information on the Survey Sheet of the Plans to become completely familiar with the soil types and densities that will be encountered during the driving. Have an awareness of the existence and depth of layers of rocks and boulders and the depth to impenetrable hard pan or bed rock. With the above information in mind, the inspector will be in a better position to make quick and intelligent decisions should problems arise during driving. Also study the Plans and Special Provisions for special requirements, and for the location of underground utilities and structures, including old road beds, pavements etc.

The inspector should make certain that the pile driving foreman correctly interprets the working points from which the pile layout is staked. While the actual staking is the Contractor's responsibility, a conscientious inspector would not proceed with the driving without verifying that the pile stakes had been properly placed. To be indifferent in matters of this importance would indicate a lack of responsibility on the part of the inspector.

The end of the pile which is to receive the pile cap should be squared off normal to the longitudinal axis of the pile. Timber piles should also be trimmed at the butt end so as to fit into the cap.

A. Test Piles

Test piles should be marked off in 0.25 m (1 ft) increments for the full length of the piles, with special markings at 1.5 m (5 ft) increments, before they are placed in the leads, to provide a means for determining the number of blows required to drive each 0.25 m (1 ft). Markings on steel or dry timber can be made quickly and easily with yellow lumber crayon or spray paint, but for freshly treated timber piles roofing discs are often used, fastened with shingle nails.

Driving a pile, particularly a test pile, should be as continuous as practical. Delays should be permitted only when they are unavoidable, or when authorized or directed by the Engineer. When it is necessary to drive piles through dense overburden, or to considerable depths through moderately heavy to heavy plastic soils, a delay in driving before reaching the required depth may permit the soil to "freeze" or "set-up" the pile sufficiently to prevent additional penetration when driving is resumed. Occasionally the Engineer may request that a pile be redriven a short distance after a delay period to determine whether or not resistance has built up during the delay period. Under some conditions the resistance is actually reduced during the delay, a phenomenon that may occur in course-grained, saturated soils.

It is to be expected that test piles will usually be longer and will be driven harder than the remaining piles in the unit, since their purpose is to provide information for authorizing length for foundation piling. It serves no purpose to continue driving when it becomes obvious that minimal additional penetration will be obtained. Keep in mind that bearings computed using dynamic formulas are only a tool to be used in determining appropriate pile lengths. Comparison of computed bearings to "design bearings" is one basis for establishing a minimum acceptable pile penetration. Routinely, pile lengths are authorized longer than the length needed based on dynamic formulas.

Driving of displacement type test piles should be continued until substantial refusal has been obtained or the driving resistance is so great there is concern regarding the capability of the pile to withstand further driving.

In some cases, plans may require minimum tip elevations which must be obtained and may require driving beyond substantial refusal. Substantial refusal is defined by the Specifications and, unless modified by the special provisions, is the minimum resistance all test piles should be driven to, unless pile damage will result. The definition for substantial refusal is related to design load, type of driving hammer, and the energy developed by the hammer. The inspector should be familiar with the term and its implications. End bearing pile should be driven to the planned hard soil layer or rock using care not to damage the piling by overdriving. It is impossible from a practical standpoint to set hard and fast rules or Specifications that would cover all situations, and this is where sound judgment must govern. Unless the inspector has had considerable experience and background, it would be prudent to seek advice from the Engineer when there is doubt about minimum pile penetration or bearing. Before making a final judgment, be certain that you know the job requirements and that you are familiar with the available soils information.

When it is found that timber test piles for a unit are of insufficient length to develop the required bearing value, and longer piles are on hand at the site for other units, it might be expedient to drive one or more of the longer piles for the unit in question. It would be advisable for the inspector to discuss such arrangements with the Project Engineer before proceeding unless there is a previous understanding regarding the inspector's authority on these matters. In the case of steel H-piles, or steel shells, the contractor should have splicing material on hand so that the test piles can be extended if necessary to obtain sufficient bearing.

In most cases, all test piles should be driven for a unit before authorizing the remaining piles for the unit. In the case of short-span pile-bent bridges, with one test pile per bent, test piles should be driven for as many bents as practicable before making pile length determinations. This is particularly desirable when the test pile locations are staggered for adjacent bents. The interior of steel shells should be visually inspected for damage prior to authorization of foundation pile lengths. The extent of damage must be included with information provided to the Bridge Office for pile length determinations.

When the Contractor has a pile driving crew tied up waiting for delivery of piling after driving the test piles, it behooves the inspector to make special effort to expedite the authorization of foundation pile lengths. The Bridge Office will review test pile information and authorize lengths immediately when urgency is indicated.

A complete record must be kept of the driving. If preboring is required for the piles which are to be authorized on the basis of results of the test piles, then preboring should also be required for the test piles. The diameter of the auger and the depth of preboring should be given when calling in test pile results and indicated on the test pile reports. The blow count should be noted for each 0.25 m (1 ft) and for any abrupt change within a given range. Complete notes may give important clues regarding possible damage to, or breakage of, the pile below the ground surface. When a steel pile is driven to rock, especially a battered pile to sloping rock, the pile may "refuse" momentarily or may slow down, then bend and take off down the rock slope. An alert inspector who has studied the soils logs will often be able to detect this the moment it occurs. See Figure A, B, E, F 5-393.165 for examples of test pile reports.

B. Foundation Piling

When the test piles have been driven and the final lengths have been authorized, inspection of the foundation pile driving is still a very important function of the Bridge Construction Inspector. Not only does the inspector make certain that the piles are driven to adequate bearing and penetration, but also avoids excessive driving which may result in severe damage to the piles. Either extreme may render the piles useless, and could result in the failure of a foundation. In general, appropriate bearing capacity criteria for foundation piling is established from test pile data and application of criteria for substantial refusal to driving of foundation piling is not appropriate.

Make certain that all piles for a unit have been satisfactorily driven, and redriven where required, before indicating approval of the driving for that unit. Do not delay the contractor unnecessarily, but do not let him pressure you into making a premature determination. If in doubt, consult with the Engineer.

Establish cut-off elevation and measure and record the cut-off length for each pile. Require the specified preservative treatment of 2452.3F3 for the top of treated timber piles.

Following is a list of some of the responsibilities and duties of the inspector on a pile driving operation.

MAKE CERTAIN:

1. that the pile locations have been staked (by the contractor) and checked (by the State) before driving is started. Where driving within a cofferdam, the pile lines should be marked off in both directions on the cofferdam walers and struts, with proper allowance for batter when necessary.

2. that the pile material has been inspected in accordance with the requirements. The final inspection and acceptance will be at the site of the work. Even though the material may have passed previous inspection, it may have been damaged in handling or shipment (this is particularly true of timber piles). The thickness of the steel in H-piles and shells should be checked, and a visual inspection made of the general condition of the piles, including welds on welded Steel Shells, and the flange to web connections on H-piles.

   Review the Mill Test Reports to verify that the material is of domestic origin.

3. that the equipment meets requirements (hammer is qualified).

4. that the piles are properly prepared for driving.

5. that the welder (if steel H-piles or shells are to be used) has passed Mn/DOT qualifying tests. All splices should be made in accordance with approved standard details for the type of pile.

6. that the length and diameter of the pile is measured and recorded before being placed in the leads.

7. that the pile is properly positioned (usually by digging a small hole for the tip of the pile with a pointed shovel at the staked location for timber piles).

8. that the pile is plumb, or at the specified batter.

9. that the driving cap fits properly on the head of the pile. An improperly fitting pile cap, particularly on a timber pile, could create a hazard in addition to damaging the pile. "Chasers" are not permitted as transmittal of hammer impact to the pile cannot be assured.

10. that the pile is properly supported laterally so as to avoid "whip" when driving, particularly if there is a noticeable bow in the length of the pile.

11. it is sometimes necessary to secure the leads with guy ropes to control their position.

12. when possible, to insist on starting the pile with reduced energy until the pile is well seated, particularly for timber piles.

13. to observe the action of the pile very closely as it starts downward, and insist on immediate correction if it moves out of position, plumbness, or specified batter.

14. to observe the operation of pile hammers and determine whether or not they are functioning properly when full power is supplied. Energy reductions in excess of 25 percent may be necessary if hammer is not operating properly.

15. to note whether or not the pile and the hammer are in alignment. A pile can be easily damaged when not properly aligned with the hammer, and the damage may be blamed by the foreman to "overdriving."

16. to observe the pile closely, especially timber piles, for evidence of cracks, splits, or fractures, which may cause sudden failure and perhaps an accident. Timber piles may release splinters large enough to cause serious injury when dropping from considerable height.

17. to observe any strain that may be created on the equipment due to high booms and/or heavy loads.

18. that "penetration per blow" readings are taken well in advance of final penetration, when this is possible or practical, particularly when approaching the "substantial refusal" range.

19. that timber piles are not driven to cut-off length since some damage is done to the top wood fibers by the hammer impact even though this may not be visible. Provide for at least 150 mm (6 in.) of cut-off. Steel, piles or shells may be driven to cut-off if the top of the pile is in reasonably good condition.

20. that final penetration measurements are made by the inspector and are not delegated to the worker.

21. to drive all piling to the bearing capacity satisfactory to the Engineer, to substantial refusal or to the required penetration. Do not continue driving a pile after substantial refusal has been obtained merely to reduce cut-off length, unless a shallow hard layer is suspected, or unless the contract specifies a minimum depth of penetration.

22. to signal the foreman when the pile has been driven to the required penetration or substantial refusal. If there is a failure to signal the operator immediately, and a failure occurs as a result, the accident is the contractor's responsibility. As the Specifications are currently written, Mn/DOT will be responsible for any damage which occurs to the pile if there is an order to continue driving beyond substantial refusal.

23. as the top of the pile approaches cut-off elevation, inspect it visually for evidence of damage, and avoid, if possible, the inclusion of damaged areas below cut-off. Slightly deformed steel sections are not necessarily considered as damaged.

24. to observe piles which have been driven to determine whether or not they may be heaving when driving adjacent piles. Order redriving of piles which have heaved. Plastic soils sometimes have this characteristic, particularly with closely spaced tapered piles.

25. to require removal of earth that may have swelled above the bottom of footing elevation during pile driving. Areas which were over-excavated may be backfilled with approved material and compacted or filled with concrete. See the appropriate section of Specification 2451.3.

26. when obstructions, such as rocks or boulders, are encountered near the surface they should be removed. If this cannot be done, then the pile pattern may have to be modified. Consult the Project Engineer, or the Bridge Office, if necessary.

The inspection procedure for trestle type piles is much the same as for foundation piles, with the following additions:

1. Require that guides or templates be used when necessary in order to keep the piles in proper alignment and at the correct batter. The tolerances are necessarily more rigid than are those for foundation piles.

2. Timber or plank guides, set to correct grade and slope, should be used when timber pile cut-offs are made, since the pile cap should fit snugly on the pile without the use of shims or fills. Cutting off trestle piles should be done only by experienced sawyers or welders. Super-elevated roadways, or skewed bridges on grade, often require that the caps be placed on a slope, thereby necessitating that the cut-off guides also be placed on a slope.

5-393.163 PILE BEARING TABLES

Pile bearings should be computed using the appropriate formula from Specification 2452.3D. Be sure to verify whether the foundation was designed using ASD or LRFD methodology, as different dynamic formulas will be used depending on the design methodology. As an aid in computing pile capacities a computer program has been developed that allows the user to input the required data and the program generates the bearing capacity (see Figure A 5-393.163). This computer program is available from the Bridge Office website at www.dot.state.mn.us/bridge Click on the "downloads" button and look for "Pile Capacity Program". Figure B 5-393.163 provides a tabulated conversion from blows per foot to penetration in inches per blow for input into the dynamic formulas. Figures C 5-393.163 and D 5-393.163 provide examples of tables that can be developed to determine pile capacity for various pile lengths and penetrations. Similar tables can be developed using a spreadsheet program also available on the Bridge Office website. Click on the "downloads" button and look for "Pile Bearing Table".

5-393.164 PILE INFORMATION TABLES

Figure A 5-393.164 lists information regarding energy, ram weight, max stroke for many hammer types. This information was obtained from the GRLWEAP General Users' Manual which is provided courtesy of Gobal, Rausch, Likins & Associates. Figures B-F 5-393.164 tabulate pertinent data relating to H-piles, timber piles and pipe pile dimensions. This may be used for pile mass or weight estimation by the inspector.

5-393.165 TEST PILE AND PILE DRIVING REPORTS

Test pile driving results should be transmitted to the Bridge Construction Unit as promptly as possible after completion of driving, except when additional test piles are to be driven before an authorization can be made. Unless it is convenient to hand-carry the reports, the quickest method of obtaining a determination is to relay the test pile information by telephone, fax, or e-mail.

As soon as practical after phoning in the test pile results, the reports should be prepared and forwarded as per the distribution list on the back of the reports.

A sketch should be shown on the back side of the report, indicating the location of the test pile covered by that report with relation to the footing lines. Also show direction by a North Arrow, the centerline of piers, the centerline of bearing for abutments, the centerline of bridge, and any dimensions necessary to determine the location of the test pile. If the test pile is a batter pile, indicate the direction of batter with a short arrow extending from the pile location.

When test piles are redriven after a delay, as provided for in the Specifications under certain conditions, the length of time delay as well as computed bearings before and after redriving should be noted on the report. See Figures M-P 5-393.165 for examples.

When preboring for test piles, be certain to note the depth prebored and the diameter of the auger used for preboring. The design load should be shown on all test pile reports.

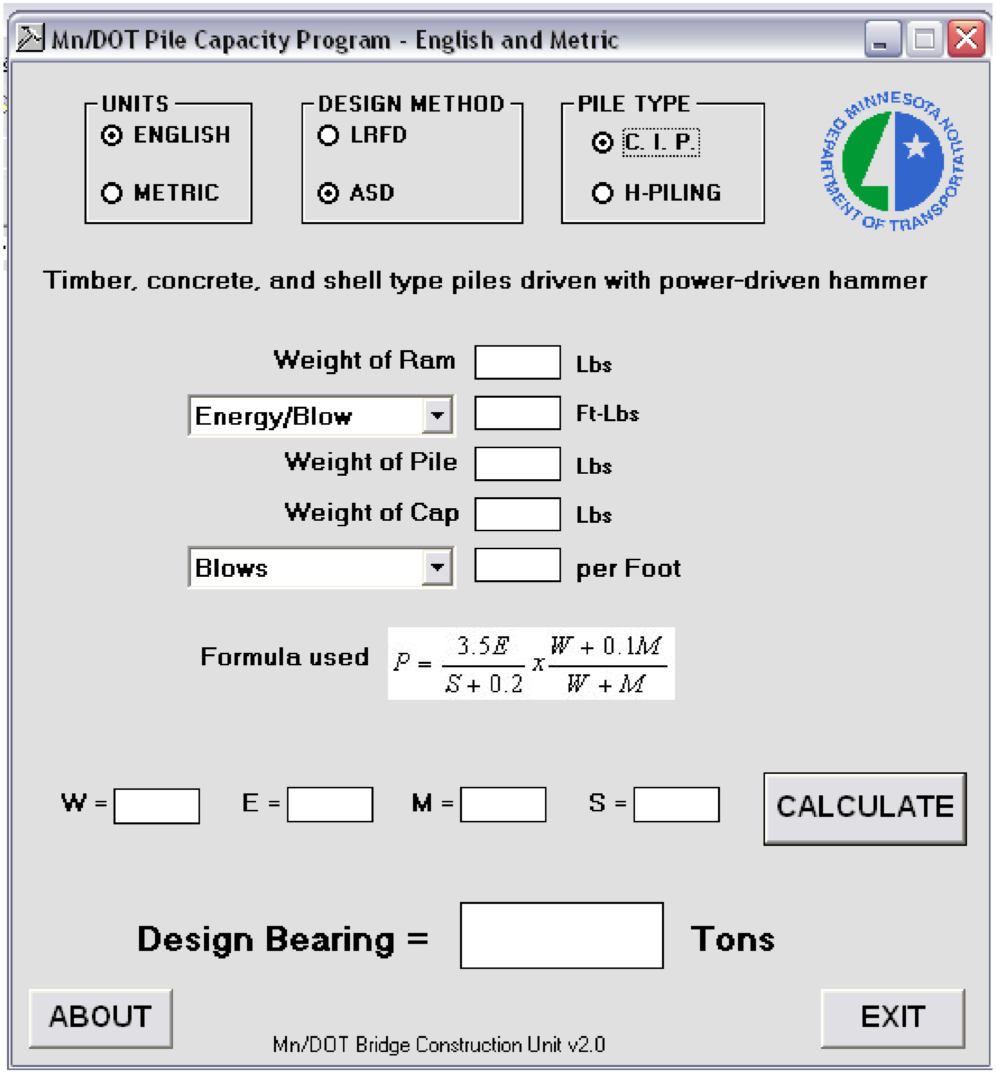
Be certain to follow the instructions on the reverse side of the Test Pile Report form. Reports are often received which clearly indicate that the person preparing them had not read these instructions, or did not understand them. If there is any question regarding the information requested, which cannot be resolved, please do not hesitate to call Bridge Construction Unit personnel.

Examples of test pile reports are shown in Figures A, B and E, F and I, J and M, N 5-393.165.

The pile driving report should be prepared as soon as the piles have been driven for a unit. See the distribution information on the reverse side of the reports for what to do with the finished reports. When the bridge carries railroad traffic, an additional copy should be made for each railroad involved, and should be sent to the Mn/DOT Office of Railroad Administration. In the event there is some question regarding the adequacy of the piles driven for a unit, the matter should be discussed immediately with your supervisor without waiting for a review of the reports by the Bridge Office.

The instructions for preparing the report are defined on the reverse side of the form, and should be read and followed. Many reports are received which indicate the instructions have not been read. Examples of pile driving reports are shown in Figures C, D and G, H and K, L and O, P 5-393.165.

For drop hammers, entries in the column headed Final Energy Per Blow should be equal to the weight of the hammer multiplied by the height of free fall. Appropriate reductions should be made for factors which tend to reduce the energy delivered by a drop hammer, such as noticeable bounce, heavy batter, line drag, poor hammer pile alignment, etc.


Mn/DOT Pile Capacity Program - English and Metric
UNITS
ENGLISH
METRIC
DESIGN METHOD
LRFD
ASD
PILE TYPE
C. I. P.
H-PILING
MINNESOTA DEPARTMENT OF TRANSPORTATION
Timber, concrete, and shell type piles driven with power-driven hammer
Weight of Ram
Lbs
Energy/Blow
Ft-Lbs
Weight of Pile
Lbs
Weight of Cap
Lbs
Blows
per Foot
Formula used
$P = \frac{3.5E}{S + 0.2} x \frac{W + 0.1M}{W + M}$
W =
E =
M =
S =
CALCULATE
Design Bearing =
Tons
ABOUT
EXIT
Mn/DOT Bridge Construction Unit v2.0

CONVERSION CHART

BLOWS/FOOT TO INCHES OF PENETRATION PER BLOW

Blows per 1 Foot	Penet. per Blow (Inches)	Blows per 1 Foot	Penet. per Blow (Inches)	Blows per 1 Foot	Penet. per Blow (Inches)	Blows per 1 Foot	Penet. per Blow (Inches)	Blows per 1 Foot	Penet. per Blow (Inches)	Blows per 1 Foot	Penet. per Blow (Inches)	Blows per 1 Foot	Penet. per Blow (Inches)	Blows per 1 Foot	Penet. per Blow (Inches)	Blows per 1 Foot	Penet. per Blow (Inches)
1	12.000	38	0.316	75	0.160	112	0.107	149	0.081	186	0.065	223	0.054	260	0.046	297	0.040
2	6.000	39	0.308	76	0.158	113	0.106	150	0.080	187	0.064	224	0.054	261	0.046	298	0.040
3	4.000	40	0.300	77	0.156	114	0.105	151	0.079	188	0.064	225	0.053	262	0.046	299	0.040
4	3.000	41	0.293	78	0.154	115	0.104	152	0.079	189	0.063	226	0.053	263	0.046	300	0.040
5	2.400	42	0.286	79	0.152	116	0.103	153	0.078	190	0.063	227	0.053	264	0.045	301	0.040
6	2.000	43	0.279	80	0.150	117	0.103	154	0.078	191	0.063	228	0.053	265	0.045	302	0.040
7	1.714	44	0.273	81	0.148	118	0.102	155	0.077	192	0.063	229	0.052	266	0.045	303	0.040
8	1.500	45	0.267	82	0.146	119	0.101	156	0.077	193	0.062	230	0.052	267	0.045	304	0.039
9	1.333	46	0.261	83	0.145	120	0.100	157	0.076	194	0.062	231	0.052	268	0.045	305	0.039
10	1.200	47	0.255	84	0.143	121	0.099	158	0.076	195	0.062	232	0.052	269	0.045	306	0.039
11	1.091	48	0.250	85	0.141	122	0.098	159	0.075	196	0.061	233	0.052	270	0.044	307	0.039
12	1.000	49	0.245	86	0.140	123	0.098	160	0.075	197	0.061	234	0.051	271	0.044	308	0.039
13	0.923	50	0.240	87	0.138	124	0.097	161	0.075	198	0.061	235	0.051	272	0.044	309	0.039
14	0.857	51	0.235	88	0.136	125	0.096	162	0.074	199	0.060	236	0.051	273	0.044	310	0.039
15	0.800	52	0.231	89	0.135	126	0.095	163	0.074	200	0.060	237	0.051	274	0.044	311	0.039
16	0.750	53	0.226	90	0.133	127	0.094	164	0.073	201	0.060	238	0.050	275	0.044	312	0.038
17	0.706	54	0.222	91	0.132	128	0.094	165	0.073	202	0.059	239	0.050	276	0.043	313	0.038
18	0.667	55	0.218	92	0.130	129	0.093	166	0.072	203	0.059	240	0.050	277	0.043	314	0.038
19	0.632	56	0.214	93	0.129	130	0.092	167	0.072	204	0.059	241	0.050	278	0.043	315	0.038
20	0.600	57	0.211	94	0.128	131	0.092	168	0.071	205	0.059	242	0.050	279	0.043	316	0.038
21	0.571	58	0.207	95	0.126	132	0.091	169	0.071	206	0.058	243	0.049	280	0.043	317	0.038
22	0.545	59	0.203	96	0.125	133	0.090	170	0.071	207	0.058	244	0.049	281	0.043	318	0.038
23	0.522	60	0.200	97	0.124	134	0.090	171	0.070	208	0.058	245	0.049	282	0.043	319	0.038
24	0.500	61	0.197	98	0.122	135	0.089	172	0.070	209	0.057	246	0.049	283	0.042	320	0.038
25	0.480	62	0.194	99	0.121	136	0.088	173	0.069	210	0.057	247	0.049	284	0.042	321	0.037
26	0.462	63	0.190	100	0.120	137	0.088	174	0.069	211	0.057	248	0.048	285	0.042	322	0.037
27	0.444	64	0.188	101	0.119	138	0.087	175	0.069	212	0.057	249	0.048	286	0.042	323	0.037
28	0.429	65	0.185	102	0.118	139	0.086	176	0.068	213	0.056	250	0.048	287	0.042	324	0.037
29	0.414	66	0.182	103	0.117	140	0.086	177	0.068	214	0.056	251	0.048	288	0.042	325	0.037
30	0.400	67	0.179	104	0.115	141	0.085	178	0.067	215	0.056	252	0.048	289	0.042	326	0.037
31	0.387	68	0.176	105	0.114	142	0.085	179	0.067	216	0.056	253	0.047	290	0.041	327	0.037
32	0.375	69	0.174	106	0.113	143	0.084	180	0.067	217	0.055	254	0.047	291	0.041	328	0.037
33	0.364	70	0.171	107	0.112	144	0.083	181	0.066	218	0.055	255	0.047	292	0.041	329	0.036
34	0.353	71	0.169	108	0.111	145	0.083	182	0.066	219	0.055	256	0.047	293	0.041	330	0.036
35	0.343	72	0.167	109	0.110	146	0.082	183	0.066	220	0.055	257	0.047	294	0.041	331	0.036
36	0.333	73	0.164	110	0.109	147	0.082	184	0.065	221	0.054	258	0.047	295	0.041	332	0.036
37	0.324	74	0.162	111	0.108	148	0.081	185	0.065	222	0.054	259	0.046	296	0.041	333	0.036

PILE BEARING TABLE IN kN

Energy per Blow (E): 40451 Nm (Reduce Maximum Rated Energy by 25% or field measure.)

Ram Mass (W): 2195 kilograms

C.I.P. (.1) / H-Pile (.2): 0.1 (? see formula)

Make and Model of Hammer : Delmag D 15

Formula used : $\frac{289\,E}{S+5} \cdot \frac{W + ?\,M}{W + M}$

Mass of Pile Plus Mass of Cap in Kilograms (M)

Blows per 0.25 (m)	(S) Penet. Per Blow (mm)	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	3000	3200	3400	3600	3800	4000
6	41.7	180	175	171	167	163	159	155	152	149	146	143	140	138	135	133	130	128	126	124	120	117	114	110	108	105
7	35.7	206	201	196	191	186	182	178	174	171	167	164	161	158	155	152	150	147	145	142	138	134	130	127	123	120
8	31.3	232	226	220	215	209	205	200	196	192	188	184	181	177	174	171	168	165	162	160	155	150	146	142	139	135
9	27.8	256	249	243	237	232	226	221	217	212	208	204	200	196	192	189	186	183	180	177	171	166	162	157	153	149
10	25.0	280	273	266	259	253	247	242	237	232	227	222	218	214	210	206	203	200	196	193	187	182	177	172	167	163
11	22.7	303	295	287	280	274	268	262	256	251	246	241	236	232	227	223	220	216	212	209	202	197	191	186	181	177
12	20.8	325	317	309	301	294	287	281	275	269	264	258	253	249	244	240	236	232	228	224	217	211	205	200	194	190
13	19.2	347	338	329	321	313	306	299	293	287	281	275	270	265	260	256	251	247	243	239	232	225	219	213	207	202
14	17.9	367	358	349	340	332	325	317	311	304	298	292	286	281	276	271	266	262	258	253	246	238	232	225	220	214
15	16.7	388	377	368	359	350	342	335	328	321	314	308	302	296	291	286	281	276	272	267	259	252	244	238	232	226
16	15.6	407	397	386	377	368	360	352	344	337	330	324	317	311	306	300	295	290	285	281	272	264	257	250	243	237
17	14.7	426	415	405	395	385	376	368	360	353	346	339	332	326	320	314	309	304	299	294	285	277	269	262	255	249
18	13.9	445	433	422	412	402	393	384	376	368	360	353	347	340	334	328	322	317	312	307	297	289	280	273	266	259
19	13.2	462	450	439	428	418	409	400	391	383	375	368	361	354	347	341	335	330	324	319	309	300	292	284	277	270
20	12.5	480	467	456	444	434	424	415	406	397	389	381	374	367	360	354	348	342	336	331	321	311	303	295	287	280
21	11.9	497	484	472	460	449	439	429	420	411	403	395	387	380	373	366	360	354	348	343	332	322	313	305	297	290
22	11.4	513	500	487	475	464	453	443	434	425	416	408	400	393	385	379	372	366	360	354	343	333	324	315	307	299
23	10.9	529	515	502	490	478	468	457	447	438	429	421	412	405	397	390	384	377	371	365	354	343	334	325	316	309
24	10.4	545	530	517	504	493	481	471	460	451	442	433	425	417	409	402	395	388	382	376	364	353	344	334	326	318
26	9.6	575	560	545	532	520	508	496	486	476	466	457	448	440	432	424	417	410	403	396	384	373	362	353	344	335
28	8.9	603	587	572	558	545	533	521	510	499	489	479	470	461	453	445	437	430	423	416	403	391	380	370	361	352
30	8.3	630	613	598	583	569	556	544	532	521	511	501	491	482	473	465	457	449	442	434	421	409	397	387	377	367
32	7.8	655	638	622	607	593	579	566	554	542	531	521	511	501	492	484	475	467	459	452	438	425	413	402	392	382
34	7.4	680	662	645	630	615	601	587	575	563	551	540	530	520	511	501	493	485	477	469	455	441	429	417	406	396
37	6.8	714	696	678	661	646	631	617	604	591	579	568	557	546	536	527	518	509	501	493	478	464	451	438	427	417
40	6.3	746	727	709	691	675	659	645	631	618	605	593	582	571	561	551	541	532	523	515	499	484	471	458	446	435
43	5.8	777	756	737	719	702	686	671	656	643	630	617	605	594	583	573	563	553	544	536	519	504	490	477	464	453
48	5.2	823	801	781	762	744	727	711	695	681	667	654	641	629	618	607	596	586	577	567	550	534	519	505	492	480
52	4.8	856	834	813	793	774	756	740	724	709	694	681	667	655	643	632	621	610	600	591	572	556	540	526	512	499
60	4.2	916	892	870	848	828	809	791	774	758	743	728	714	701	688	676	664	653	642	632	612	595	578	562	548	534
66	3.8	956	931	907	885	864	844	826	808	791	775	759	745	731	718	705	693	681	670	659	639	620	603	587	571	557
80	3.1	1034	1007	981	957	935	913	893	874	855	838	821	806	791	776	762	749	737	725	713	691	671	652	634	618	603
96	2.6	1104	1075	1048	1023	999	976	954	933	914	895	878	861	845	829	815	801	787	774	762	738	717	697	678	660	644
120	2.1	1185	1155	1125	1098	1072	1047	1024	1002	981	961	942	924	907	890	875	859	845	831	818	793	769	748	728	709	691
160	1.6	1280	1246	1215	1185	1157	1131	1105	1082	1059	1038	1017	997	979	961	944	928	912	897	883	856	830	807	785	765	746
240	1.0	1390	1354	1319	1287	1257	1228	1201	1175	1150	1127	1105	1083	1063	1044	1025	1008	991	974	959	929	902	877	853	831	811
480	0.5	1521	1481	1444	1409	1375	1344	1314	1286	1259	1233	1209	1186	1164	1142	1122	1103	1084	1066	1049	1017	987	959	934	910	887

PILE BEARING TABLE IN TONS CAPACITY

Rated Energy Per Blow *39780 **ft. lb.** **Ram Wt.** 4840 **lb** **Make of Hammer** Delmag D-22

***Single acting - not field measured**

Formula used: $\frac{3.5\,E}{S + 0.2} \times \frac{W + 0.1\,M}{W + M} \times 0.75$

Blows per foot	Penet. Per Blow (in.)	1.016	1.020	1.024	1.028	1.032	1.036	1.040	1.043	1.047	1.051	1.055	1.058	1.062	1.066	1.069	1.073	1.076	1.085	1.093	1.102	1.110	1.118	1.126	1.134	1.142
		800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4500	5000	5500	6000	6500	7000	7500	8000
6	2.000	21	20	19	19	18	18	17	17	17	16	16	16	15	15	15	14	14	13	13	12	12	11	11	11	10
7	1.714	24	23	22	22	21	21	20	20	19	19	18	18	18	17	17	17	16	15	15	14	14	13	13	12	12
8	1.500	27	26	25	24	24	23	23	22	21	21	21	20	20	19	19	19	18	17	17	16	15	15	14	14	13
9	1.333	30	29	28	27	26	26	25	25	24	23	23	22	22	21	21	21	20	19	18	18	17	17	16	15	15
10	1.200	32	31	31	30	29	28	27	27	26	26	25	24	24	23	23	23	22	21	20	19	19	18	17	17	16
11	1.091	35	34	33	32	31	31	30	29	28	28	27	26	26	25	25	24	24	23	22	21	20	20	19	18	18
12	1.000	38	37	36	35	34	33	32	31	30	30	29	28	28	27	27	26	26	25	24	23	22	21	20	20	19
13	0.923	41	39	38	37	36	35	34	33	33	32	31	31	30	29	29	28	28	26	25	24	23	23	22	21	20
14	0.857	43	42	40	39	38	37	36	35	34	34	33	32	32	31	30	30	29	28	27	26	25	24	23	22	22
15	0.800	45	44	43	42	40	39	38	37	37	36	35	34	33	33	32	32	31	30	28	27	26	25	24	24	23
16	0.750	48	46	45	44	43	41	40	39	38	38	37	36	35	35	34	33	32	31	30	29	28	27	26	25	24
17	0.706	50	48	47	46	44	43	42	41	40	39	38	38	37	36	35	35	34	32	31	30	29	28	27	26	25
18	0.667	52	51	49	48	47	45	44	43	42	41	40	39	38	38	37	36	35	34	33	31	30	29	28	27	26
19	0.632	55	53	52	50	49	47	46	45	44	43	42	41	40	40	39	38	37	36	34	33	32	30	29	28	28
20	0.600	57	55	53	52	51	49	48	47	46	45	44	43	42	41	40	39	39	37	35	34	33	32	31	30	29
21	0.571	59	57	56	54	53	51	50	49	47	46	45	44	43	43	42	41	40	38	37	35	34	33	32	31	30
22	0.546	61	59	57	55	54	53	51	50	49	48	47	46	45	44	43	42	41	39	38	36	35	34	33	31	31
23	0.522	63	61	59	58	56	55	53	52	51	50	49	47	46	46	45	44	43	41	39	38	36	35	34	33	32
24	0.500	65	63	61	59	58	56	55	54	52	51	50	49	48	47	46	45	44	42	40	39	37	36	35	34	33
26	0.462	69	67	65	63	61	60	58	57	55	54	53	52	51	50	49	48	47	45	43	41	40	38	37	36	35
28	0.429	72	70	68	66	64	63	61	59	58	57	55	54	53	52	51	50	49	47	45	43	42	40	39	37	36
30	0.400	76	73	71	69	67	66	64	62	61	60	58	57	56	55	54	53	51	49	47	45	44	42	41	39	38
32	0.375	78	76	74	72	70	68	66	65	63	62	60	59	58	57	55	54	53	51	49	47	45	44	42	41	40
34	0.353	83	80	78	76	74	72	70	68	66	65	64	62	61	60	58	57	56	54	51	49	48	46	44	43	42
37	0.324	87	85	82	80	78	76	74	72	70	69	67	66	64	63	62	61	59	57	54	52	50	49	47	45	44
40	0.300	91	88	86	83	81	79	77	75	73	72	70	68	67	66	64	63	62	59	57	54	52	51	49	47	46
43	0.279	95	92	89	87	84	82	80	78	76	75	73	71	70	68	67	66	64	62	59	57	55	53	51	49	48
48	0.250	101	98	95	92	90	88	85	83	81	80	78	76	74	73	71	70	69	66	63	60	58	56	54	52	51
52	0.231	106	102	99	97	94	92	89	87	85	83	81	79	78	76	75	73	72	69	66	63	61	59	57	55	53
60	0.200	113	110	107	104	101	98	96	94	91	89	87	85	84	82	80	79	77	74	71	68	65	63	61	59	57
66	0.182	119	116	112	109	106	104	101	99	96	94	92	90	88	86	85	83	81	78	74	72	69	67	64	62	60
80	0.150	130	126	122	119	116	113	110	107	104	102	100	98	96	94	92	90	88	84	81	78	75	72	70	67	66
96	0.125	140	136	132	128	125	121	118	115	113	110	108	105	103	101	99	97	95	91	87	84	81	78	75	73	71
120	0.100	151	147	143	139	135	131	128	125	122	119	117	114	111	109	107	105	103	98	94	91	87	84	81	79	77
160	0.075	165	160	155	151	147	143	140	136	133	130	127	124	121	119	117	115	112	107	103	99	95	92	79	86	83
240	0.050	182	176	171	166	162	158	154	150	146	143	140	137	134	131	128	126	123	118	113	109	105	101	98	94	92
480	0.025	201	196	190	185	180	175	171	167	162	159	155	152	149	146	143	140	137	131	126	121	116	112	108	105	102

The first header row gives the Multiplying Factor for Steel H Piles; the second gives M (Weight of Pile Plus Weight of Cap).

Hammer Data File Listing (October 2005)

Hammer Type: OED-Open End Diesel CED-Closed End Diesel ECH-External Combustion

Hammer Mfgr.	Model No.	Max Enegy (ft-lbs)	Ram Wt. (lbs)	Stroke (ft)	Hammer Type
APE	D 1	1,950	308	6.67	OED
APE	D 8-32	18,000	1,760	10.25	OED
APE	D 16-32	39,360	3,530	11.25	OED
APE	D 19-32	42,820	4,190	10.25	OED
APE	D 19-42	42,820	4,190	10.60	OED
APE	D 25-32	57,880	5,512	10.50	OED
APE	D 30-32	70,070	6,610	10.60	OED
APE	D 36-32	84,060	7,930	10.60	OED
APE	D 46-32	107,480	10,140	10.60	OED
APE	D 62-22	161,460	13,660	11.82	OED
APE	D 80-23	196,990	17,620	11.18	OED
APE	D 100-13	246,300	22,030	11.18	OED
APE	D 125-32	307,290	27,560	11.15	OED
APE	5.4mT	26,000	12,000	2.17	ECH
APE	7.2mT	51,300	16,200	3.17	ECH
APE	10-60	80,000	20,000	4.00	ECH
APE	HI 400U	400,000	80,000	5.00	ECH
BANUT	3 Tonnes	17,340	6,610	2.62	ECH
BANUT	4 Tonnes	23,140	8,820	2.62	ECH
BANUT	S3000	26,040	6,615	3.94	ECH
BANUT	5 Tonnes	28,920	11,020	2.62	ECH
BANUT	S4000	34,720	8,820	3.94	ECH
BANUT	6 Tonnes	34,720	13,230	2.62	ECH
BANUT	7 Tonnes	40,490	15,430	2.62	ECH
BANUT	S5000	43,410	11,025	3.94	ECH
BANUT	S6000	52,090	13,230	3.94	ECH
BANUT	S8000	69,450	17,640	3.94	ECH
BANUT	S10000	86,810	22,050	3.94	ECH
BERMINGH	B200	18,000	2,000	9.00	OED
BERMINGH	B200 5	21,000	2,000	10.50	OED
BERMINGH	B2005	24,120	2,680	9.00	OED
BERMINGH	B250 5	26,250	2,500	10.50	OED
BERMINGH	B225	29,250	3,000	9.75	OED
BERMINGH	B2505	35,400	3,000	11.80	OED
BERMINGH	B3005	35,400	3,000	11.80	OED
BERMINGH	B300	40,310	3,750	10.75	OED
BERMINGH	B300 M	40,310	3,750	10.75	OED
BERMINGH	B400 4.8	43,200	4,800	9.00	OED
BERMINGH	B400 5.0	45,000	5,000	9.00	OED
BERMINGH	B3505	47,200	4,000	11.80	OED
BERMINGH	B400	53,750	5,000	10.75	OED
BERMINGH	B400 M	53,750	5,000	10.75	OED
BERMINGH	B4005	59,000	5,000	11.80	OED
BERMINGH	B4505	77,880	6,600	11.80	OED
BERMINGH	B550 C	88,000	11,000	8.00	OED
BERMINGH	B5005	92,040	7,800	11.80	OED
BERMINGH	B5505	108,560	9,200	11.80	OED
BERMINGH	B6005	160,950	13,640	11.80	OED
BERMINGH	B6505	207,680	17,600	11.80	OED
BERMINGH	B6505 C	253,000	22,000	11.50	OED
BERMINGH	B23	22,990	2,800	8.21	CED
BERMINGH	B23 5	22,990	2,800	8.21	CED
Bruce	SGH-0312	26,040	6,610	3.94	ECH
Bruce	SGH-0512	43,420	11,020	3.94	ECH
Bruce	SGH-0712	60,800	15,432	3.94	ECH
Bruce	SGH-1012	86,860	22,046	3.94	ECH
BSP	SL20	14,110	3,308	4.27	ECH
BSP	HH1.5	16,250	3,303	4.92	ECH
BSP	SL30	21,690	5,510	3.94	ECH
BSP	HH3	26,020	6,611	3.94	ECH
BSP	CX40	28,210	6,613	4.27	ECH
BSP	CX50	37,610	8,818	4.27	ECH
BSP	HH5	43,370	11,020	3.94	ECH
BSP	CX60	47,010	11,022	4.27	ECH
BSP	CX75	52,070	13,227	3.94	ECH
BSP	CX85	60,750	15,431	3.94	ECH
BSP	HH7	60,780	15,427	3.94	ECH
BSP	HH8	69,500	17,640	3.94	ECH
BSP	CX110	78,110	19,840	3.94	ECH
BSP	HH9	78,170	19,840	3.94	ECH
BSP	1.2	95,540	24,250	3.94	ECH
BSP	1.5	119,310	24,250	4.92	ECH
BSP	CX165	120,930	24,249	4.99	ECH
BSP	1.2	121,590	30,860	3.94	ECH
BSP	CG180	131,920	26,454	4.99	ECH
BSP	CX180	131,920	26,454	4.99	ECH
BSP	1.2	138,870	35,272	3.94	ECH
BSP	1.5	151,830	30,860	4.92	ECH
BSP	CG210	153,910	30,863	4.99	ECH
BSP	CX210	153,910	30,863	4.99	ECH
BSP	1.5	173,540	35,272	4.92	ECH
BSP	HH20	173,580	44,090	3.94	ECH
BSP	HH20S	173,580	44,090	3.94	ECH
BSP	CG240	175,900	35,272	4.99	ECH
BSP	CX240	175,900	35,272	4.99	ECH
BSP	CG270	197,880	39,681	4.99	ECH
BSP	CX270	197,880	39,681	4.99	ECH
BSP	CG300	219,870	44,090	4.99	ECH
BSP	CX300	219,870	44,090	4.99	ECH
BSP	HA30	260,370	66,135	3.94	ECH
BSP	HA40	347,160	88,180	3.94	ECH
CONMACO	C 50	15,000	5,000	3.00	ECH
CONMACO	C 65	19,500	6,500	3.00	ECH
CONMACO	C 550	25,000	5,000	5.00	ECH
CONMACO	C 50E5	25,000	5,000	5.00	ECH
CONMACO	C 80	26,000	8,000	3.25	ECH
CONMACO	C 565	32,500	6,500	5.00	ECH
CONMACO	C 65E5	32,500	6,500	5.00	ECH
CONMACO	C 100	32,500	10,000	3.25	ECH
CONMACO	C 115	37,380	11,500	3.25	ECH
CONMACO	C 80E5	40,000	8,000	5.00	ECH
CONMACO	C 140	42,000	14,000	3.00	ECH
CONMACO	C 160	48,750	16,250	3.00	ECH
CONMACO	C 100E5	50,000	10,000	5.00	ECH
CONMACO	C 160 **	51,780	17,260	3.00	ECH
CONMACO	C 115E5	57,500	11,500	5.00	ECH
CONMACO	C 200	60,000	20,000	3.00	ECH
CONMACO	C 125E5	62,500	12,500	5.00	ECH
CONMACO	C 300	90,000	30,000	3.00	ECH
CONMACO	C 5200	100,000	20,000	5.00	ECH
CONMACO	C 200E5	100,000	20,000	5.00	ECH
CONMACO	C 5300	150,000	30,000	5.00	ECH
CONMACO	C 300E5	150,000	30,000	5.00	ECH
CONMACO	C 5450	225,000	45,000	5.00	ECH
CONMACO	C 5700	350,000	70,000	5.00	ECH
CONMACO	C 6850	510,000	85,000	6.00	ECH
DAWSON	HPH1200	8,720	2,300	3.79	ECH
DAWSON	HPH1800	13,720	3,300	4.16	ECH
DAWSON	HPH2400	17,320	4,189	4.13	ECH
DAWSON	HPH6500	46,980	10,250	4.58	ECH
DELMAG	D 5	10,510	1,100	9.62	OED
DELMAG	D 5-42	10,560	1,100	9.60	OED
DELMAG	D 6-32	13,520	1,322	10.23	OED
DELMAG	D 8-22	20,100	1,760	12.05	OED
DELMAG	D 12	22,610	2,750	10.80	OED
DELMAG	D 15	27,090	3,300	10.80	OED

Hammer Mfgr.	Model No.	Max Enegy (ft-lbs)	Ram Wt. (lbs)	Stroke (ft)	Hammer Type
DELMAG	D 12-32	31,330	2,820	11.81	OED
DELMAG	D 12-42	33,300	2,820	11.81	OED
DELMAG	D 14-42	34,500	3,086	11.81	OED
DELMAG	D 16-32	40,200	3,520	11.76	OED
DELMAG	D 22	40,610	4,910	9.50	OED
DELMAG	D 19-32	42,440	4,000	11.76	OED
DELMAG	D 19-52	43,240	4,000	11.86	OED
DELMAG	D 19-42	43,240	4,000	11.86	OED
DELMAG	D 22-02	48,500	4,850	13.44	OED
DELMAG	D 22-13	48,500	4,850	13.44	OED
DELMAG	D 22-23	51,220	4,850	13.44	OED
DELMAG	D 21-42	55,750	4,630	14.00	OED
DELMAG	D 30	59,730	6,600	9.50	OED
DELMAG	D 30-02	66,200	6,600	13.44	OED
DELMAG	D 30-13	66,200	6,600	13.44	OED
DELMAG	D 25-32	66,340	5,510	13.76	OED
DELMAG	D 30-23	73,790	6,600	13.44	OED
DELMAG	D 30-32	75,440	6,600	13.73	OED
DELMAG	D 36	83,820	7,930	10.57	OED
DELMAG	D 36-02	83,820	7,930	12.98	OED
DELMAG	D 36-13	83,820	7,930	19.98	OED
DELMAG	D 36-23	88,500	7,930	12.98	OED
DELMAG	D 44	90,150	9,500	9.52	OED
DELMAG	D 36-32	90,560	7,930	13.14	OED
DELMAG	D 46-13	96,530	10,140	12.94	OED
DELMAG	D 46	107,080	10,140	10.57	OED
DELMAG	D 46-02	107,080	10,140	12.94	OED
DELMAG	D 46-23	107,080	10,140	12.94	OED
DELMAG	D 46-32	122,190	10,140	13.10	OED
DELMAG	D 55	125,000	11,860	11.15	OED
DELMAG	D 62-02	152,450	13,660	12.71	OED
DELMAG	D 62-12	152,450	13,660	12.71	OED
DELMAG	D 62-22	164,600	13,660	13.26	OED
DELMAG	D 80-12	186,240	17,620	12.87	OED
DELMAG	D 80-23	212,500	17,620	13.05	OED
DELMAG	D100-13	265,670	22,066	13.50	OED
DELMAG	D120-42	301,790	26,450	11.81	OED
DELMAG	D125-42	313,630	27,560	13.60	OED
DELMAG	D150-42	377,330	33,070	11.81	OED
DELMAG	D200-42	492,040	44,090	16.83	OED
DKH	PH-5	43,400	11,023	3.94	ECH
DKH	PH-7	60,750	15,432	3.94	ECH
DKH	PH-7S	60,750	15,432	3.94	ECH
DKH	PH-10	86,790	22,045	3.94	ECH
DKH	PH-13	112,830	28,658	3.94	ECH
DKH	PH-20	216,980	44,090	4.92	ECH
DKH	PH-30	325,470	66,135	4.92	ECH
DKH	PH-40	433,960	88,180	4.92	ECH
FAIRCHLD	F-32	32,550	10,850	3.00	ECH
FAIRCHLD	F-45	45,000	15,000	3.00	ECH
FEC	FEC 1200	22,500	2,750	8.18	OED
FEC	FEC 1500	27,090	3,300	8.21	OED
FEC	D-18	39,700	3,970	11.76	OED
FEC	FEC 2500	50,000	5,500	9.09	OED
FEC	FEC 2800	55,990	6,160	9.09	OED
FEC	FEC 3000	63,030	6,600	9.55	OED
FEC	FEC 3400	73,000	7,480	9.76	OED
HERA	1250	25,340	2,809	9.02	OED
HERA	1500	30,400	3,371	9.02	OED
HERA	1900	44,410	4,190	10.60	OED
HERA	2500	50,670	5,618	9.02	OED
HERA	2800	56,760	6,292	9.02	OED
HERA	3500	70,940	7,865	9.02	OED
HERA	5000	101,350	11,236	9.02	OED
HERA	5700	115,540	12,809	9.02	OED
HERA	6200	125,670	13,933	9.02	OED
HERA	7500	152,020	16,854	9.02	OED
HERA	8800	178,370	19,775	9.02	OED
HITACHI	HNC65	56,420	14,330	3.94	ECH
HITACHI	HNC80	69,430	17,636	3.94	ECH
HITACHI	HNC100	86,790	22,045	3.94	ECH
HITACHI	HNC125	108,490	27,557	3.94	ECH
HMC	19D	14,000	3,500	4.00	ECH
HMC	28B	21,000	7,000	3.00	ECH
HMC	28A	28,000	7,000	4.00	ECH
HMC	38D	28,000	7,000	4.00	ECH
HMC	62	46,000	11,500	4.00	ECH
HMC	86	64,000	16,000	4.00	ECH
HMC	119	88,000	22,000	4.00	ECH
HMC	149	110,000	27,500	4.00	ECH
HMC	187	138,000	34,500	4.00	ECH
HPSI	650	32,500	6,500	5.00	ECH
HPSI	110	44,000	11,000	4.00	ECH
HPSI	1000	50,000	10,000	5.00	ECH
HPSI	150	60,000	15,000	4.00	ECH
HPSI	154	61,600	15,400	4.00	ECH
HPSI	200	80,000	20,000	4.00	ECH
HPSI	2000	80,000	20,000	4.00	ECH
HPSI	1605	83,000	16,600	5.00	ECH
HPSI	225	90,000	22,500	4.00	ECH
HPSI	2005	95,100	19,020	5.00	ECH
HPSI	3005	154,320	30,865	5.00	ECH
HPSI	3505	176,320	35,265	5.00	ECH
HYPOTHET	EX 4	23,380	2,750	8.50	OED
ICE	30-S	22,500	3,000	7.67	OED
ICE	32-S	26,010	3,000	10.67	OED
ICE	I-12	30,210	2,821	11.50	OED
ICE	40-S	40,000	4,000	10.17	OED
ICE	42-S	42,000	4,090	10.42	OED
ICE	I-19	43,240	4,015	12.30	OED
ICE	60-S	59,990	7,000	10.42	OED
ICE	70-S	70,000	7,000	10.17	OED
ICE	I-30	75,480	6,615	12.60	OED
ICE	80-S	80,000	8,000	12.42	OED
ICE	90-S	90,000	9,000	10.17	OED
ICE	I-36	90,670	7,940	12.10	OED
ICE	100-S	100,000	10,000	12.00	OED
ICE	200-S	100,000	20,000	6.00	OED
ICE	I-46	107,740	10,145	12.12	OED
ICE	120-S	120,000	12,000	12.42	OED
ICE	120S-15	132,450	15,000	12.25	OED
ICE	I-62	164,980	14,600	14.25	OED
ICE	205-S	170,000	20,000	10.50	OED
ICE	I-80	212,400	17,700	13.50	OED
ICE	70	21,000	7,000	3.00	ECH
ICE	75	30,000	7,500	4.00	ECH
ICE	110-SH	37,720	11,500	3.28	ECH
ICE	115-SH	37,950	11,500	3.30	ECH
ICE	115	46,000	11,500	4.00	ECH
ICE	160-SH	64,000	16,000	4.00	ECH
ICE	160	64,000	16,000	4.00	ECH
ICE	220	88,000	22,000	4.00	ECH
ICE	275	110,000	27,500	4.00	ECH
ICE	180	8,130	1,730	4.70	CED
ICE	440	18,560	4,000	4.64	CED
ICE	422	23,120	4,000	5.78	CED
ICE	520	30,370	5,070	5.99	CED
ICE	640	40,620	6,000	6.77	CED
ICE	660	51,630	7,570	6.82	CED
ICE	1070	72,600	10,000	7.26	CED
IHC	SC-30	21,810	3,760	5.80	ECH
IHC	S-35	25,530	6,630	3.85	ECH
IHC	SC-40	29,860	5,510	5.42	ECH
IHC	SC-50	36,810	7,290	5.05	ECH
IHC	SC-60	44,950	13,300	3.38	ECH
IHC	S-70	51,250	7,730	6.63	ECH
IHC	SC-75	54,800	12,150	4.51	ECH
IHC	S-90	65,900	9,940	6.63	ECH
IHC	SC-110	81,890	17,460	4.69	ECH
IHC	S-120	89,370	13,480	6.63	ECH
IHC	SC-150	109,350	24,300	4.50	ECH
IHC	S-150	110,060	16,600	6.63	ECH

Hammer Mfgr.	Model No.	Max Enegy (ft-lbs)	Ram Wt. (lbs)	Stroke (ft)	Hammer Type
IHC	S-200	145,640	22,000	6.62	ECH
IHC	SC-200	152,510	30,200	5.05	ECH
IHC	S-280	205,310	30,060	6.83	ECH
IHC	S-400	292,600	44,200	6.62	ECH
IHC	S-500	366,090	55,300	6.62	ECH
IHC	S-600	443,540	67,000	6.62	ECH
IHC	S-900	658,360	99,450	6.62	ECH
IHC	S-1200	891,050	134,600	6.62	ECH
IHC	S-1800	1,170,300	166,000	7.05	ECH
IHC	S-2300	1,681,480	254,000	6.62	ECH
J&M	115 HIH	46,000	11,500	4.00	ECH
J&M	160 HIH	64,000	16,000	4.00	ECH
J&M	220 HIH	88,000	22,000	4.00	ECH
J&M	275 HIH	110,000	27,500	4.00	ECH
J&M	345 HIH	138,000	34,500	4.00	ECH
JUNTTAN	HHK 3	26,040	6,613	3.94	ECH
JUNTTAN	HHK 3A	26,040	6,613	3.94	ECH
JUNTTAN	HHK 4	34,720	8,818	3.94	ECH
JUNTTAN	HHK 4A	34,720	8,818	3.94	ECH
JUNTTAN	HHK 5	43,400	11,022	3.94	ECH
JUNTTAN	HHK 5A	43,400	11,022	3.94	ECH
JUNTTAN	HHK 6	52,070	13,227	3.94	ECH
JUNTTAN	HHK 6A	52,070	13,227	3.94	ECH
JUNTTAN	HHU 5A	54,240	11,022	4.92	ECH
JUNTTAN	HHK 7	60,750	15,431	3.94	ECH
JUNTTAN	HHK 7A	60,750	15,431	3.94	ECH
JUNTTAN	HHK 7S	75,940	15,431	4.92	ECH
JUNTTAN	HHU 7A	75,940	15,431	4.92	ECH
JUNTTAN	HHK 9A	78,110	19,840	3.94	ECH
JUNTTAN	HHK 10	86,790	22,045	3.94	ECH
JUNTTAN	HHK 9S	97,640	19,840	4.92	ECH
JUNTTAN	HHU 9A	97,640	19,840	4.92	ECH
JUNTTAN	HHK 12	104,150	26,454	3.94	ECH
JUNTTAN	HHK 12A	104,150	26,454	3.94	ECH
JUNTTAN	HHK 14	121,510	30,863	3.94	ECH
JUNTTAN	HHK 14A	121,510	30,863	3.94	ECH
JUNTTAN	HHK 12S	130,190	26,454	4.92	ECH
JUNTTAN	HHU 12A	130,190	26,454	4.92	ECH
JUNTTAN	HHK 16A	138,870	35,272	3.94	ECH
JUNTTAN	HHK 14S	151,880	30,863	4.92	ECH
JUNTTAN	HHU 14A	151,880	30,863	4.92	ECH
JUNTTAN	HHK 18A	156,220	39,681	3.94	ECH
JUNTTAN	HHK 16S	173,580	35,272	4.92	ECH
JUNTTAN	HHU 16A	173,580	35,272	4.92	ECH
JUNTTAN	HHK 18S	195,280	39,681	4.92	ECH
JUNTTAN	HHK 20S	216,980	44,090	4.92	ECH
JUNTTAN	HHK 25S	271,220	55,112	4.92	ECH
JUNTTAN	HHK 36S	390,560	79,362	4.92	ECH
KOBE	K 13	25,430	2,870	8.86	OED
KOBE	K22-Est	45,350	4,850	9.35	OED
KOBE	K 25	51,520	5,510	9.35	OED
KOBE	K 35	72,180	7,720	9.35	OED
KOBE	K 45	92,750	9,920	9.35	OED
KOBE	KB 60	130,180	13,230	9.84	OED
KOBE	KB 80	173,580	17,640	9.84	OED
LINKBELT	LB 180	8,100	1,730	4.68	CED
LINKBELT	LB 312	15,020	3,860	3.89	CED
LINKBELT	LB 440	18,200	4,000	4.55	CED
LINKBELT	LB 520	26,310	5,070	5.19	CED
LINKBELT	LB 660	51,630	7,570	6.82	CED
MENCK	MHF3-3	24,760	7,054	3.51	ECH
MENCK	MHF3-4	30,960	8,818	3.51	ECH
MENCK	MHF5-5	38,690	11,022	3.51	ECH
MENCK	MHF3-5	38,690	11,022	3.51	ECH
MENCK	MRBS 500	45,070	11,020	4.09	ECH
MENCK	MHF5-6	46,430	13,227	3.51	ECH
MENCK	MHF3-6	46,430	13,227	3.51	ECH
MENCK	MH 68	49,180	7,720	6.37	ECH
MENCK	MHF5-7	54,170	15,431	3.51	ECH
MENCK	MHF3-7	54,170	15,431	3.51	ECH
MENCK	MHF5-8	61,910	17,636	3.51	ECH

Hammer Mfgr.	Model No.	Max Enegy (ft-lbs)	Ram Wt. (lbs)	Stroke (ft)	Hammer Type
MENCK	750	67,770	16,530	4.10	ECH
MENCK	MH 96	69,430	11,020	6.30	ECH
MENCK	MHF5-9	69,650	19,840	3.51	ECH
MENCK	MHF5-10	77,390	22,045	3.51	ECH
MENCK	MHF5-11	85,130	24,249	3.51	ECH
MENCK	MHF5-12	92,870	26,454	3.51	ECH
MENCK	850	93,280	18,960	4.92	ECH
MENCK	MH 145	104,800	16,530	6.34	ECH
MENCK	14	108,340	30,863	3.51	ECH
MENCK	MHU135T	110,590	17,987	6.15	ECH
MENCK	150S	110,590	17,987	6.15	ECH
MENCK	135T	110,590	17,987	6.15	ECH
MENCK	MHU150S	110,590	17,987	6.15	ECH
MENCK	MRBS110	123,430	24,250	5.09	ECH
MENCK	15	124,730	33,060	3.77	ECH
MENCK	MRBS150	135,590	33,070	4.10	ECH
MENCK	195	143,740	21,361	6.73	ECH
MENCK	220	162,170	24,838	6.53	ECH
MENCK	200T	162,240	26,745	6.07	ECH
MENCK	20	166,270	44,070	3.77	ECH
MENCK	MRBS180	189,810	38,580	4.92	ECH
MENCK	300S	221,200	35,729	6.19	ECH
MENCK	270T	221,200	35,729	6.19	ECH
MENCK	MRBS250	225,950	55,110	4.10	ECH
MENCK	MRBS250	225,950	55,110	4.10	ECH
MENCK	MRBS250	262,110	63,930	4.10	ECH
MENCK	400	294,820	51,087	5.77	ECH
MENCK	400T	324,360	52,449	6.18	ECH
MENCK	MRBS300	325,360	66,130	4.92	ECH
MENCK	MHU500T	405,530	65,958	6.15	ECH
MENCK	500T	405,530	65,958	6.15	ECH
MENCK	600	442,280	75,522	5.86	ECH
MENCK	600B	457,030	65,958	6.93	ECH
MENCK	MHU600B	457,030	65,958	6.93	ECH
MENCK	600T	486,630	80,393	6.05	ECH
MENCK	MRBS460	498,940	101,410	4.92	ECH
MENCK	MRBS390	513,340	86,860	5.91	ECH
MENCK	MRBS500	542,330	110,230	4.92	ECH
MENCK	700T	567,720	92,883	6.11	ECH
MENCK	800S	604,570	99,931	6.05	ECH
MENCK	750T	604,570	99,931	6.05	ECH
MENCK	840S	619,220	92,883	6.67	ECH
MENCK	MRBS700	631,400	154,000	4.10	ECH
MENCK	1000	737,380	126,980	5.81	ECH
MENCK	MRBS600	759,230	132,270	5.74	ECH
MENCK	MRBS800	867,740	176,370	4.92	ECH
MENCK	MHU1200	884,840	145,705	6.07	ECH
MENCK	MHU1100	899,660	145,705	6.17	ECH
MENCK	MRBS880	954,530	194,010	4.92	ECH
MENCK	MHU1500	1,106,070	178,944	6.18	ECH
MENCK	1700	1,253,240	207,152	6.05	ECH
MENCK	MHU1700	1,400,860	227,360	6.16	ECH
MENCK	MHU1900	1,400,860	227,360	6.16	ECH
MENCK	2100	1,548,290	257,177	6.02	ECH
MENCK	MBS1250	1,581,830	275,580	5.74	ECH
MENCK	MHU2700	1,990,190	318,765	6.24	ECH
MENCK	3000	2,211,900	370,229	5.97	ECH
MITSUBIS	M 14	25,250	2,970	8.50	OED
MITSUBIS	MH 15	28,140	3,310	8.50	OED
MITSUBIS	M 23	43,010	5,060	8.50	OED
MITSUBIS	MH 25	46,840	5,510	8.50	OED
MITSUBIS	M 33	61,710	7,260	8.50	OED
MITSUBIS	MH 35	65,620	7,720	8.50	OED
MITSUBIS	M 43	80,410	9,460	8.50	OED
MITSUBIS	MH 45	85,430	10,050	8.50	OED
MITSUBIS	MH 72B	135,150	15,900	8.50	OED
MITSUBIS	MH 80B	149,600	17,600	8.50	OED
MKT	DE 10	8,800	1,100	11.00	OED
MKT	DE 20	16,000	2,000	9.00	OED
MKT	DE 30	22,400	2,800	10.00	OED
MKT	SA	23,800	2,800	13.00	OED

Hammer Mfgr.	Model No.	Max Enegy (ft-lbs)	Ram Wt. (lbs)	Stroke (ft)	Hammer Type
MKT	DE 30B	23,800	2,800	10.00	OED
MKT	DE 40	32,000	4,000	10.00	OED
MKT	DE 42/35	35,000	3,500	13.50	OED
MKT	DA55B SA	40,000	5,000	12.00	OED
MKT	DE 42/35	42,000	4,200	13.50	OED
MKT	DE 50B	42,500	5,000	11.00	OED
MKT	DE 50C	50,000	5,000	13.00	OED
MKT	DE 70B	59,500	7,000	12.00	OED
MKT	DE 70C	70,000	7,000	13.00	OED
MKT	No. 5	1,000	200	5.00	ECH
MKT	No. 6	2,500	400	6.25	ECH
MKT	No. 7	4,150	800	5.19	ECH
MKT	9B3	8,750	1,600	5.47	ECH
MKT	10B3	13,110	3,000	4.37	ECH
MKT	C5-Air	14,200	5,000	2.84	ECH
MKT	C5-Steam	16,200	5,000	3.24	ECH
MKT	S-5	16,250	5,000	3.25	ECH
MKT	11B3	19,150	5,000	3.83	ECH
MKT	C826 Air	21,200	8,000	2.65	ECH
MKT	C826 Stm	24,400	8,000	3.05	ECH
MKT	S-8	26,000	8,000	3.25	ECH
MKT	MS-350	30,800	7,720	3.99	ECH
MKT	S 10	32,500	10,000	3.25	ECH
MKT	S 14	37,520	14,000	2.68	ECH
MKT	MS 500	44,000	11,000	4.00	ECH
MKT	S 20	60,000	20,000	3.00	ECH
MKT	DA 35B	21,000	2,800	7.50	CED
MKT	DA 35C	21,000	2,800	7.50	CED
MKT	DA 45	30,720	4,000	7.68	CED
MKT	DA 55B	38,200	5,000	7.64	CED
MKT	DA 55C	38,200	5,000	7.64	CED
MKT 20	DE333020	20,000	2,000	11.50	OED
MKT 30	DE333020	28,000	2,800	11.50	OED
MKT 33	DE333020	33,000	3,300	11.50	OED
MKT 40	DE333020	40,000	4,000	11.50	OED
MKT 50	DE70/50B	50,000	5,000	12.00	OED
MKT 70	DE70/50B	70,000	7,000	12.00	OED
MKT 110	DE110150	110,000	11,000	13.50	OED
MKT 150	DE110150	150,000	15,000	13.50	OED
MVE	M-19	49,380	4,015	12.30	OED
MVE	M-30	83,350	6,615	12.60	OED
PILECO	D8-22	18,660	1,760	11.60	OED
PILECO	D12-42	29,890	2,820	11.80	OED
PILECO	D19-42	42,510	4,010	12.60	OED
PILECO	D25-32	58,410	5,510	13.70	OED
PILECO	D30-32	70,070	6,610	13.70	OED
PILECO	D36-32	84,160	7,940	13.10	OED
PILECO	D46-32	107,480	10,140	13.10	OED
PILECO	D62-22	161,310	13,670	13.20	OED
PILECO	D80-23	197,570	17,640	12.90	OED
PILECO	D100-13	246,850	22,040	13.50	OED
PILECO	D125-32	308,670	27,560	14.30	OED
PILECO	D160-32	395,080	35,275	14.30	OED
Pilemast	24-750	1,500	750	2.00	ECH
Pilemast	24-900	1,800	900	2.00	ECH
Pilemast	24-2000	4,000	2,000	2.00	ECH
Pilemast	24-2500	5,000	2,500	2.00	ECH
Pilemast	36-3000	9,000	3,000	3.00	ECH
RAYMOND	R 1	15,000	5,000	3.00	ECH
RAYMOND	R 1S	19,500	6,500	3.00	ECH
RAYMOND	R 65C	19,500	6,500	3.00	ECH
RAYMOND	R 65CH	19,500	6,500	3.00	ECH
RAYMOND	R 0	24,380	7,500	3.25	ECH
RAYMOND	R 80C	24,480	8,000	3.06	ECH
RAYMOND	R 80CH	24,480	8,000	3.06	ECH
RAYMOND	R 2/0	32,500	10,000	3.25	ECH
RAYMOND	R 3/0	40,620	12,500	3.25	ECH
RAYMOND	R 150C	48,750	15,000	3.25	ECH
RAYMOND	R 4/0	48,750	15,000	3.25	ECH
RAYMOND	R 5/0	56,880	17,500	3.25	ECH
RAYMOND	R 30X	75,000	30,000	2.50	ECH
RAYMOND	R 8/0	81,250	25,000	3.25	ECH
RAYMOND	R 40X	100,000	40,000	2.50	ECH
RAYMOND	R 60X	150,000	60,000	2.50	ECH
Twinwood	V20B	35,580	9,038	3.94	ECH
Twinwood	V100D	87,660	22,265	3.94	ECH
Twinwood	V160B	140,580	35,708	3.94	ECH
Twinwood	V400A	263,840	67,016	3.94	ECH
UDDCOMB	H2H	16,620	4,404	3.77	ECH
UDDCOMB	H3H	24,880	6,600	3.77	ECH
UDDCOMB	H4H	33,180	8,800	3.77	ECH
UDDCOMB	H5H	41,470	11,000	3.77	ECH
UDDCOMB	H6H	49,760	13,200	3.77	ECH
UDDCOMB	H8H	82,190	17,600	4.67	ECH
UDDCOMB	H10H	86,880	22,050	3.94	ECH
VULCAN	VUL 02	7,260	3,000	2.42	ECH
VULCAN	VUL 30C	7,260	3,000	2.42	ECH
VULCAN	VUL 01	15,000	5,000	3.00	ECH
VULCAN	VUL 50C	15,100	5,000	3.02	ECH
VULCAN	VUL 65C	19,180	6,500	2.95	ECH
VULCAN	VUL 06	19,500	6,500	3.00	ECH
VULCAN	65CA	19,570	6,500	3.01	ECH
VULCAN	VUL 80C	24,480	8,000	3.06	ECH
VULCAN	VUL 505	25,000	5,000	5.00	ECH
VULCAN	VUL 85C	25,990	8,520	3.05	ECH
VULCAN	VUL 08	26,000	8,000	3.25	ECH
VULCAN	VUL 506	32,500	6,500	5.00	ECH
VULCAN	VUL 010	32,500	10,000	3.25	ECH
VULCAN	100C	32,900	10,000	3.29	ECH
VULCAN	140C	35,980	14,000	2.57	ECH
VULCAN	VUL 012	39,000	12,000	3.25	ECH
VULCAN	VUL 508	40,000	8,000	5.00	ECH
VULCAN	VUL 014	42,000	14,000	3.00	ECH
VULCAN	VUL 016	48,750	16,250	3.00	ECH
VULCAN	VUL 510	50,000	10,000	5.00	ECH
VULCAN	200C	50,200	20,000	2.51	ECH
VULCAN	VUL 512	60,000	12,000	5.00	ECH
VULCAN	VUL 020	60,000	20,000	3.00	ECH
VULCAN	VUL 320	60,000	20,000	3.00	ECH
VULCAN	VUL 030	90,000	30,000	3.00	ECH
VULCAN	VUL 330	90,000	30,000	3.00	ECH
VULCAN	VUL 520	100,000	20,000	5.00	ECH
VULCAN	400C	113,600	40,000	2.84	ECH
VULCAN	VUL 040	120,000	40,000	3.00	ECH
VULCAN	VUL 340	120,000	40,000	3.00	ECH
VULCAN	VUL 530	150,000	30,000	5.00	ECH
VULCAN	600C	179,160	60,000	2.99	ECH
VULCAN	VUL 060	180,000	60,000	3.00	ECH
VULCAN	VUL 360	180,000	60,000	3.00	ECH
VULCAN	VUL 540	200,000	40,900	4.89	ECH
VULCAN	VUL 560	300,000	62,500	4.80	ECH
VULCAN	3100	300,000	100,000	3.00	ECH
VULCAN	5100	500,000	100,000	5.00	ECH
VULCAN	5150	750,000	150,000	5.00	ECH
VULCAN	6300	1,800,000	300,000	6.00	ECH
IWEN, B	GRADE A	1,000	1,000	1.00	TLC

H Bearing Piles - Dimensions and Mass (Metric Units)

Nominal Size and Mass	Mass per meter (kg/m)	Depth (mm)	Flange		Web Thickness (mm)
			Width (mm)	Thickness (mm)	
HP 360 x 174	174	361	378	20.4	20.4
HP 360 x 152	152	356	376	17.9	17.9
HP 360 x 132	132	351	373	15.6	15.6
HP 360 x 108	108	346	370	12.8	12.8
HP 310 x 110	110	308	310	15.5	15.4
HP 310 x 94	94	303	308	13.1	13.1
HP 310 x 79	79	299	306	11.0	11.0
HP 250 x 85	85	254	260	14.4	14.4
HP 250 x 62	62	246	256	10.7	10.5
HP 200 x 54	54	204	207	11.3	11.3

H Bearing Piles - Dimensions and Weight (English Units)

Nominal Size and Weight	Weight per Foot (lb/ft)	Depth (in.)	Flange		Web Thickness (in.)
			Width (in.)	Thickness (in.)	
HP 14 x 117	117	14 1/4	14 7/8	13/16	13/16
HP 14 x 102	102	14	14 3/4	11/16	11/16
HP 14 x 89	89	13 7/8	14 3/4	5/8	5/8
HP 14 x 73	73	13 5/8	14 5/8	1/2	1/2
HP 12 x 74	74	12 1/8	12 1/4	5/8	5/8
HP 12 x 63	63	12	12 1/8	1/2	1/2
HP 12 x 53	53	11 3/4	12	7/16	7/16
HP 10 x 57	57	10	10 1/4	9/16	9/16
HP 10 x 42	42	9 3/4	10 1/8	7/16	7/16
HP 8 x 36	36	8	8 1/8	7/16	7/16

APPROXIMATE MASS OF TREATED TIMBER PILES (kg)

Length meters	Tip Dia. mm	BUTT DIA. (mm) 280	290	300	310	320	330	340	350	360	370	380	390	400
5	200	165	170	180	185	195	205	210	220	230	235	245	255	265
	225	180	190	200	205	210	220	230	235	245	255	265	275	285
	250	200	205	215	225	230	240	250	255	265	275	285	295	305
6	200	195	205	215	225	235	245	255	265	275	285	295	305	315
	225	215	225	235	245	255	265	275	285	295	305	315	330	340
	250	240	250	255	265	275	285	300	310	320	330	340	355	365
7	200			250	260	270	285	295	305	320	330	345	355	370
	225			275	285	295	310	320	330	345	355	370	385	395
	250			300	310	325	335	345	360	370	385	400	410	425
8	200			287	300	310	325	335	350	365	380	395	405	420
	225			315	325	340	355	365	380	395	410	425	440	455
	250			345	355	370	385	395	410	425	440	455	470	485
9	200			320	335	350	365	380	395	410	425	440	460	475
	225			355	365	380	395	412	425	445	460	475	495	510
	250			385	400	415	430	445	460	480	495	510	530	545
10	200			360	375	390	405	420	440	455	475	490	510	530
	225			390	410	425	440	460	475	490	510	530	550	565
	250			430	445	460	480	495	515	530	550	570	590	610
11	200			395	410	430	445	465	480	500	520	540	560	580
	225			430	450	465	485	505	520	540	560	580	600	625
	250			470	490	510	525	545	565	585	605	625	645	670
12	175			390	410	430	445	465	485	505	525	545	570	590
	200			430	450	465	485	505	525	545	570	590	610	635
	225			470	490	510	530	550	570	590	610	635	655	680
14	175						520	545	565	590	615	635	660	685
	200						565	590	615	640	660	685	715	740
	225						615	640	665	690	715	740	765	795
16	175						595	620	645	675	700	730	755	785
	200						650	675	700	730	755	785	815	845
	225						705	730	760	790	815	845	875	905
18	175						670	700	725	760	790	820	850	885
	200						730	760	790	820	850	885	915	950
	175						745	775	810	840	875	910	945	985
20	200						810	845	875	910	945	980	1020	1055
	175						820	855	890	925	965	1000	1040	1080
22	200						890	925	965	1000	1040	1080	1120	1161
	150						820	855	895	930	972	1015	1055	1095
24	175						890	930	970	1010	1050	1095	1135	1180

Note:
Masses shown are based on 720 kg/m^3, which is approximate average of commonly used types of treated timber piles. These weights are considered sufficiently accurate to be used for computing pile bearings. Massses for diameters which differ from those shown may be interpolated or extrapolated as the case may be. See Specification 3471 for minimum diameter requirements.

The above table may also be used for green, untreated softwood piles. For air-dry softwood piles, multiply by 0.80.

APPROXIMATE WEIGHT OF TREATED TIMBER PILES (lbs.)

Length (ft.)	Tip Dia. (in.)	BUTT DIA. (in.)										
		11	11 1/2	12	12 1/2	13	13 1/2	14	14 1/2	15	15 1/2	16
16	8	360	382	400	420	440	460	490	510	540	560	590
	9	390	420	440	460	480	500	530	550	580	600	630
	10	430	460	480	500	520	550	570	600	620	650	680
20	8	450	470	500	520	550	580	610	640	670	700	730
	9	490	520	550	570	600	630	660	690	720	750	790
	10	540	570	600	620	650	680	710	750	780	810	840
25	8			620	660	690	730	760	800	840	880	920
	9			680	720	750	790	820	860	900	940	980
	10			740	780	820	850	890	930	970	1010	1060
30	8			750	790	830	870	910	960	1000	1050	1100
	9			820	860	900	940	990	1040	1080	1130	1180
	10			890	940	980	1020	1070	1120	1170	1220	1270
35	8			870	920	970	1010	1070	1120	1170	1230	1280
	9			950	1000	1050	1100	1150	1210	1260	1320	1280
	10			1040	1090	1140	1200	1250	1300	1360	1420	1480
40	8			1000	1050	1100	1160	1220	1280	1340	1400	1470
	9			1090	1150	1200	1260	1312	1380	1440	1510	1570
	10			1190	1250	1310	1370	1430	1490	1550	1620	1690
45	8			1120	1180	1240	1300	1370	1440	1510	1580	1650
	9			1230	1290	1350	1420	1480	1550	1620	1700	1770
	10			1340	1400	1470	1540	1610	1680	1750	1820	1900
50	7			1130	1200	1260	1330	1400	1480	1550	1630	1710
	8			1240	1310	1380	1450	1522	1600	1670	1750	1830
	9			1360	1430	1500	1570	1650	1730	1800	1890	1970
55	7					1390	1470	1540	1620	1710	1790	1880
	8					1520	1600	1670	1760	1840	1930	2020
	9					1650	1730	1810	1900	1980	2070	2160
60	7					1620	1600	1680	1770	1860	1950	2050
	8					1650	1740	1830	1920	2010	2100	2200
	9					1800	1890	1980	2070	2170	2260	2360
65	7					1640	1730	1820	1920	2020	2120	2220
	8					1790	1880	1980	2080	2180	2230	2380
	7					1770	1870	1960	2070	2170	2280	2390
70	8					1930	2030	2130	2240	2340	2450	2570
	7					1900	2000	2110	2210	2330	2440	2560
75	8					2070	2170	2280	2400	2510	2630	2750
	6					2850	1960	2070	2180	2300	2420	2540
80	7					2020	2130	2250	2360	2480	2600	2730

Note:
Weights shown are based on 45 lb/ft ^{3} , which is approximate average of commonly used types of treated timber piles. These weights are considered sufficiently accurate to be used for computing pile bearings. Weights for diameters which differ from those shown may be interpolated or extrapolated as the case may be. See Specification 3471 for minimum diameter requirements.

The above table may also be used for green, untreated softwood piles. For air-dry softwood piles, multiply by 0.80.

PIPE PILES - Dimensions and Properties (Metric Units)

Size O.D. (mm)	Wall Thickness (mm)	Mass per meter (kg/m)	Section Modulus (cu. mm)	Area of Steel in Cross Section (sq. mm)	Inside Cross Sectional Area (sq. mm)	Concrete per meter pipe (cu. meters)
	3.58	22.04	173375	2817	47852	0.0479
	4.37	26.85	210082	3426	47245	0.0472
254.00	4.78	29.32	228108	3739	46929	0.0469
	5.56	34.05	263668	4342	46329	0.0463
	5.84	35.70	275630	4554	46116	0.0461
273.00	3.58	23.71	201069	3032	55522	0.0555
	4.37	28.90	243676	3688	54871	0.0549
	4.78	31.47	264651	4025	54529	0.0545
	5.56	36.61	306110	4674	53884	0.0539
	5.84	38.45	321678	4904	53652	0.0537
310.00	4.78	35.30	331510	4501	68464	0.0685
	5.56	41.01	383785	5229	67742	0.0677
	5.84	43.13	401647	5486	67477	0.0675
	6.35	46.68	435240	5954	67013	0.0670
	7.14	52.34	485384	6674	66290	0.0663
	7.92	57.96	534710	7391	65574	0.0656
	9.52	69.29	632541	8835	64129	0.0641
324.00	4.37	34.36	345439	4385	77987	0.0780
	4.78	37.44	375428	4786	77587	0.0776
	5.16	40.48	396895	5165	71400	0.0714
	5.56	43.57	434749	5562	76813	0.0768
	6.35	49.67	493087	6334	76039	0.0760
	7.14	55.73	550769	7102	75271	0.0753
406.00	5.56	54.87	691862	7005	122709	0.1227
	5.84	57.59	691534	7351	122361	0.1224
	6.35	62.58	785924	7981	121735	0.1217
	7.14	70.27	879002	8953	120768	0.1208
	7.92	77.92	970770	9921	119800	0.1198
	9.53	93.13	1151355	11876	117838	0.1178
457.00	6.35	70.52	999775	8994	155180	0.1552
	7.14	79.20	1118909	10092	154084	0.1542
	7.92	87.85	1236732	11185	152987	0.1530
	8.74	96.46	1353408	12310	151871	0.1519
508.00	6.35	78.47	1239681	10008	192677	0.1927
	7.14	88.14	1388148	11231	191451	0.1915
	7.92	97.79	1534976	12450	190232	0.1902
	9.53	116.97	1824700	14916	187767	0.1878

See Specification 3371 for minimum steel shell requirements.

PIPE PILES - Dimensions and Properties (English Units)

Size O.D. (in.)	Wall Thickness (in.)	Weight per lin. ft. (lbs.)	Section Modulus (cu. in.)	Area of Steel in Cross Section (sq. in.)	Inside Cross Sectional Area (sq. in.)	Concrete per lin. ft. pipe (cu. yds.)
10.00	0.141	14.81	10.58	4.367	74.17	0.0191
	0.172	18.04	12.82	5.311	73.23	0.0189
	0.188	19.70	13.92	5.795	72.74	0.0187
	0.219	22.88	16.09	6.730	71.81	0.0185
	0.230	23.99	16.82	7.059	71.48	0.0183
10.75	0.141	15.93	12.27	4.699	86.06	0.0221
	0.172	19.42	14.87	5.716	85.05	0.0219
	0.188	21.15	16.15	6.238	84.52	0.0217
	0.219	24.60	18.68	7.245	83.52	0.0215
	0.230	25.84	19.63	7.601	83.16	0.0213
12.00	0.188	23.72	20.23	6.976	106.12	0.0273
	0.219	27.56	23.42	8.105	105.00	0.0270
	0.230	28.98	24.51	8.504	104.59	0.0269
	0.250	31.37	26.56	9.228	103.87	0.0267
	0.281	35.17	29.62	10.345	102.75	0.0264
	0.312	38.95	32.63	11.456	101.64	0.0261
	0.375	46.56	38.60	13.694	99.40	0.0256
12.75	0.172	23.09	21.08	6.797	120.88	0.0311
	0.188	25.16	22.91	7.419	120.26	0.0309
	0.203	27.20	24.22	8.005	110.67	0.0307
	0.219	29.28	26.53	8.621	119.06	0.0306
	0.250	33.38	30.09	9.818	117.86	0.0303
	0.281	37.45	33.61	11.008	116.67	0.0300
16.00	0.219	36.87	42.22	10.858	190.20	0.0489
	0.230	38.70	42.20	11.394	189.66	0.0487
	0.250	42.05	47.96	12.370	188.69	0.0485
	0.281	47.22	53.64	13.877	187.19	0.0482
	0.312	52.36	59.24	15.377	185.69	0.0477
	0.375	62.58	70.26	18.408	182.65	0.0470
18.00	0.250	47.39	61.01	13.941	240.53	0.0619
	0.281	53.22	68.28	15.642	238.83	0.0614
	0.312	59.03	75.47	17.337	237.13	0.0610
	0.344	64.82	82.59	19.081	235.40	0.0605
20.00	0.250	52.73	75.65	15.512	298.65	0.0768
	0.281	59.23	84.71	17.408	296.75	0.0763
	0.312	65.71	93.67	19.298	294.86	0.0758
	0.375	78.60	111.35	23.120	291.04	0.0749

See Specification 3371 for minimum steel shell requirements.

MnDOT TP-02264-03 (7/97)

Minnesota Department of Transportation Office of Bridges and Structures

TEST PILE REPORT
(Metric)

SEE INSTRUCTIONS ON OTHER SIDE

PILE HAMMER DATA	PILE DATA	PROJECT DESCRIPTION
☐ DROP (Gravity) ☒ SINGLE ACTING (Power) ☐ DOUBLE ACTING (Power)	Test Pile No: 1 ☐ CIP ☒ H-Pile ☐ ______ Size: HP 250 x 85	Bridge No. 82500 S.P. No. 185-694-01 County Washington Dist. M
Make and Model: Delmag D19-42 Mass of Ram (piston) 1900 (kg) Max. Rated Energy 58028 Nm (Joule)	Length in Leads (m): 13.7 Mass of Pile (kg): 1166 Mass of Cap (kg): 780 Cut-off Elev.: 240.499	SUBSTRUCTURE ☒ Abutment West ☐ Pier No. ______
INSP. BY: Joe Pounder Jr.	INSP. PHONE NO: 1-615-747-2131	CONTRACTOR: Willdrive, Inc.

DISTANCE BELOW CUT-OFF (meters)	DROP OF HAMMER OR RAM (mm)	ENERGY PER BLOW (Nm)	BLOWS PER MIN.	BLOWS PER 250 (mm)	PENET. PER BLOW (mm)	BEARING IN kN	DISTANCE BELOW CUT-OFF (meters)	DROP OF HAMMER OR RAM (mm)	ENERGY PER BLOW (Nm)	BLOWS PER MIN.	BLOWS PER 250 (mm)	PENET. PER BLOW (mm)	BEARING IN kN
3.00		43521		8	31.3	206	11.00						
.25		↓		8	31.3	206	.25						
.50				9	27.8	228	.50						
.75				9	27.8	228	.75						
4.00				10	25.0	250	12.00						
.25				10	25.0	250	.25						
.50				11	22.7	270	.50						
.75				13	19.2	309	.75						
5.00				13	19.2	309	13.00						
.25				13	19.2	309	.25						
.50				14	17.9	327	.50						
.75				15	16.7	345	.75						
6.00				16	15.6	363	14.00						
.25				17	14.7	380	.25						
.50				17	14.7	380	.50						
.75				17	14.7	380	.75						
7.00				17	14.7	380	15.00						
.25				18	13.9	396	.25						
.50				19	13.2	411	.50						
.75				19	13.2	411	.75						
8.00				21	11.9	443	16.00						
.25				22	11.4	456	.25						
.50				23	10.9	471	.50						
.75				24	10.4	486	.75						
9.00				25	10.0	499	17.00						
.25				25	10.0	499	.25						
.50				27	9.3	524	.50						
.75				28	8.9	539	.75						
10.00				41	6.1	674	18.00						
.25				50	5.0	749	.25						
.50		↓ 20 mm/10 blows			2.0	1069	.50						
.75							.75						

DATE: Sept. 11, 2001 START DRIVING TIME: 12:30 PM END DRIVING TIME: 12:58 PM DOWN TIME: TOTAL DRIVING TIME: 28 Min.	REMARKS ON DRIVING CONDITIONS, PRE-BORING, ETC. (IDENTIFY BY PENET. DISTANCE.) Substantial Refusal = 934 kN Energy was the max. rated reduced by 25% Heat No. 51664

FORMULA USED	DESIGN BEARING (kN)	SCOUR EL.	AUTHORIZED PILE LENGTHS
$P = \frac{289E}{S+5} \times \frac{W+0.2M}{W+M}$	583		A = 10.5M
INSPECTOR SIGNATURE: Joe Pounder Jr.	PROJECT ENGINEER SIGNATURE: Joe Pounder Sr.		BRIDGE OFFICE (Initial and Date): McS 9-11-01

INSTRUCTIONS FOR COMPLETING
TEST PILE REPORT

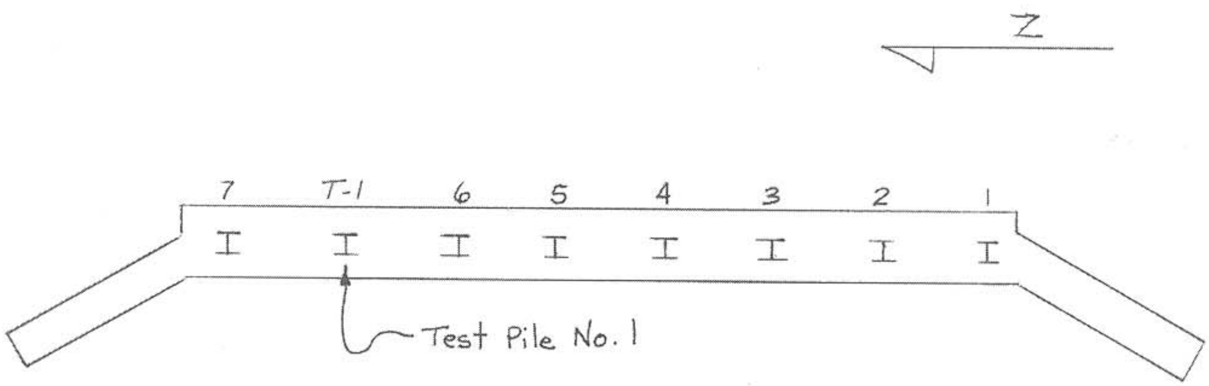
Pile Data:

1. Check type of pile as: C.I.P., H-Pile, Treated Timber, Untreated Timber, Precast Concrete, etc.
2. Show **Size** of pile; when using timber pile show butt and tip size to the nearest 5 mm. Be certain that diameters comply with the specifications. Butt diameters should be measured 1 meter from the butt end.
3. **Length in Leads** should be total length in leads.
4. Show **Mass of Pile** and **Mass of Cap** to nearest kg.
5. **INSP. BY** should be the pile driving inspector (print or type name).

Column Tabulation:

6. **ENERGY PER BLOW (Nm)** is equal to WH x 0.00981, for single power-driven hammers. When field determination of energy output is not practical, 75% of the manufacturer's maximum rated energy may be used for computations (see Spec. 2452.3E2).
7. **BLOWS PER MIN.** need not be shown for drop hammers.
8. **PENET. PER BLOW (mm)** may be based on blows per 250 mm or on a measured penetration for a given number of blows, and should be calculated to 0.1 mm.
9. **BEARING IN kN** should be shown to the nearest kN.

SHOW SKETCH BELOW
Show sketch indicating location of test pile. Show North arrow.



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Mn/DOT TP-02210-04 (7/97)

Minnesota Department of Transportation Office of Bridges and Structures

PILE DRIVING REPORT

(Metric)

SEE INSTRUCTIONS ON OTHER SIDE

PILE HAMER DATA

- ☐ DROP (Gravity)
- ☒ SINGLE ACTING (Power)
- ☐ DOUBLE ACTING (Power)

Make and Model: Delmag D19-42

Max. Rated Energy 58028 Nm (Joule)

Mass of Ram (piston) 1900 (kg)

Mass of Cap 780 (kg)

FORMULA USED

$$P = \frac{289E}{S+5} \times \frac{W+0.2M}{W+M}$$

TYPE OF PILE (include shell wall thickness): HP 250 × 85

Cut-off Elevation: 240.99

Contractor: Willdrive, Inc.

PROJECT DESCRIPTION

Bridge No. 82500

Location TH694 over TH5

County Washington Dist. Metro

S.P. No. 185-694-01

SUBSTRUCTURE

- ☒ Abutment West
- ☐ Pier No.

1 DATE DRIVEN	2 PILE NO.	3 LENGTH (m) FINAL AUTH.	3 LENGTH (m) ACTUAL TOTAL IN LEADS	4 MASS OF PILE (kg)	5 CUT-OFFS (m) ACTUAL	5 CUT-OFFS (m) Mn/DOT	6 DIST. BELOW CUT-OFF (m)	7 FINAL ENERGY PER BLOW (Nm)	8 PENET. PER BLOW (mm)	9 BEARING IN (kN)	10 NET DRVG. TIME (min.)	11 AUTH. SPLICE	12 Mn/DOT CUT-OFF DRIVEN (m)	13 REMARKS / REDRIVES
				--	Test	Pile	--							
9-11-01	T-1	13.7	13.7	1166	3.2	3.2	10.5	43521	2.0	1069	28			Heat No. 51664
				--	Foundation	Piles	--							
9-11-01	1	10.5	10.5	892	0.7	0.7	9.8	43521	3.5	881				
9-11-01	2	10.5	10.5	892	0.8	0.8	9.7	43521	3.4	891	25	1	2.5	3.5M C.O. from TP#2
9-11-01	3	10.5	10.5	892	0.2	0.2	10.3	43521	2.8	960	27			
9-11-01	4	10.5	10.5	892	0.1	0.1	10.4	43521	2.9	948				
9-11-01	5	10.5	10.5	892	0.9	0.9	9.6	43521	3.7	861				
9-11-01	6	10.5	10.5	892	0.3	0.3	10.2	43521	2.7	972				
9-11-01	7	*9.5	9.5	808	0.0	0.0	9.5	43521	3.4	891				*Actual short of Auth'd.
		72.5					69.5							
		-3.5					-2.5							Minus C.O.
		69.0	72.5		3.0	3.0	67.0			6404		1		

14. OTHER REMARKS (IDENTIFY BY PILE NO.)

SUMMARY

PLAN NUMBER AND LENGTHS: 1 T.P. @ 13.7M; 7 F.P. @ 10.7M

BRIDGE OFFICE RECOMMENDED NO. AND LENGTHS: 1 T.P. @ 13.7M; 7 F.P. @ 10.5M

15. AVERAGE DRIVEN LENGTH (m): 9.6M

DESIGN BEARING (kN): 583

15. AVERAGE BEARING (kN): 915

PAY QUANTITIES

PILING DELIVERED (m): 69.0

Mn/DOT CUT-OFFS DRIVEN (m): 2.5

PILING DRIVEN (m): 67.0

NO. OF SPLICES: 1

NO. OF REDRIVES: 0

NO. OF PILE TIP PROTECTION: 8

TEST PILES (NUMBER AND LENGTH): 1 @ 13.7 M

INSPECTOR DURING DRIVING: Joe Pounder Jr.

PROJ. ENGINEER'S SIGNATURE: Joe Pounder Sr.

DATE: 9-11-01

SHEET ______ OF ______

INSTRUCTIONS FOR COMPLETING
PILE DRIVING REPORT

General:

Field measurements to be to the nearest 0.1 (m).

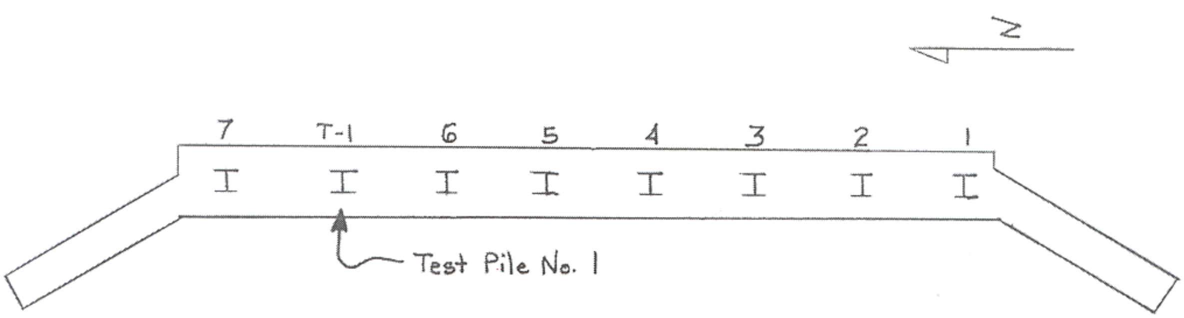
Pile Data:

(Numbers correspond with numbers on front of form)

1. **DATE DRIVEN**: Use date on which driving was completed for each pile.
2. **PILE NO.**: Show number assigned to each pile, usually the same as the driving sequence.
3. **LENGTH (m)** in leads:
   Final Auth.: Use final length authorized for payment plus any authorized test pile length which exceeds plan length. (do not include State owned cut-offs used)
   Actual Total in Leads: Use the actual total length in leads used for final driving of the pile.
4. **MASS OF PILE (kg)**: Show computed mass to nearest kg for actual total length in leads.
5. **CUT-OFFS (m)**:
   Actual: Actual length in leads less length below cut-off for each pile.
   Mn/DOT: Final authorized length in leads plus State owned cut-off placed in leads less length below cut-off for each pile.
6. **DISTANCE BELOW CUT-OFF (m)**: Actual length driven below cut-off.
7. **FINAL ENERGY PER BLOW (Nm)**: Energy developed during final blows for computing final bearing. For single acting power-driven hammers, the energy per blow is equal to WH x 0.00981. When field determination of energy output is not practical, 75% of the manufacturer's maximum rated energy may be used for computations. (see Spec. 2452.3E2)
8. **PENETRATION PER BLOW (mm)**: Calculate to 0.1 mm based on the last blows for gravity hammers and the last ten or twenty blows for power-driven hammers.
9. **BEARING IN (kN)**: Show to the nearest kN. (see Spec. 2452.5 "Notes")
10. **NET DRIVING TIME (min.)**: Actual time hammer is in operation driving the pile.
11. **AUTHORIZED SPLICES**: Number of splices eligible for payment. (see Spec. 2452.5)
12. **Mn/DOT CUT-OFFS DRIVEN (m)**: Length below cut-off less final authorized length.
13. **REMARKS**: Indicate depth of jetting or preboring and diameter of auger used, hit obstruction, butt splitting, sequence of lengths used to make up actual total length in leads, butt and tip diameters for timber piles, individual lengths of State owned cut-offs used, etc.
    REDRIVES: Use date on which redriving was completed. Show bearing after redrive to the nearest kN.
14. **OTHER REMARKS**: To be used for other pertinent information.
15. **AVERAGE DRIVEN LENGTH AND BEARING**: Do not include test piles.

SHOW SKETCH BELOW

Show outline of footing, pile locations, and number assigned each pile. Show North arrow.
Indicate test piles with prefix "T". Indicate direction of batter with arrows and note amount of batter.



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Mn/DOT TP-02264-04 (11/05)

Minnesota Department of Transportation   Office of Bridges and Structures

TEST PILE REPORT

(English)

SEE INSTRUCTIONS ON OTHER SIDE

PILE HAMMER DATA	PILE DATA	PROJECT DESCRIPTION
☐ DROP (Gravity) ☒ SINGLE ACTING (Power) ☐ DOUBLE ACTING (Power)	Test Pile No: (1) 2 3 4 5 6 or ______ ☐ CIP ☒ H-Pile ☐ ______ Size: HP 10 x 57	Bridge No.: 82500 S.P. (~~or S.A.P.~~) No.: SP 185-694-01 County: Washington Dist. M
Make and Model: Delmag D19-42	Length in Leads (ft.): 45' Weight of Pile (lbs.): 2565	SUBSTRUCTURE
Weight of ram (piston) 4190 (lbs.) Max. Rated Energy 42,800 (ft. lbs.)	Weight of Cap (lbs.): 1720 Cut-off Elev. (ft.): 789.04	☒ Abutment N S E (W) ☐ Pier No. 1 2 3 4 or ______
INSP. BY: Joe Pounder, Jr.	INSP. PHONE NO: 651-747-2131	CONTRACTOR: Willdrive, Inc.

DISTANCE BELOW CUT-OFF (feet)	DROP OF HAMMER OR RAM (feet)	ENERGY PER BLOW (ft. lbs.)	BLOWS PER MIN.	BLOWS PER FOOT	PENET. PER BLOW (inches)	BEARING IN TONS	DISTANCE BELOW CUT-OFF (feet)	DROP OF HAMMER OR RAM (feet)	ENERGY PER BLOW (ft. lbs.)	BLOWS PER MIN.	BLOWS PER FOOT	PENET. PER BLOW (inches)	BEARING IN TONS
5							37						
6							38						
7							39						
8							40						
9							41						
10	5.5	23045		18	0.667	28	42						
11	↓	↓		14	0.857	23	43						
12	↓	↓		16	0.750	25	44						
13	↓	↓		13	0.923	21	45						
14	↓	↓		17	0.706	26	46						
15	6.0	25140		21	0.571	34	47						
16	↓	↓		25	0.480	39	48						
17	↓	↓		26	0.462	40	49						
18	↓	↓		23	0.522	36	50						
19	↓	↓		23	0.522	36	51						
20	↓	↓		23	0.522	36	52						
21	↓	↓		22	0.546	35	53						
22	↓	↓		20	0.600	33	54						
23	↓	↓		19	0.632	32	55						
24				20	0.606	33	56						
25	5.5	23045		18	0.667	28	57						
26	↓	↓		17	0.706	27	58						
27	6.0	25140		20	0.600	33	59						
28	7.0	29330		35	0.343	56	60						
29	↓	↓		41	0.293	62	61						
30	↓	↓		42	0.286	63	62						
31				33	0.364	54	63						
32	8.0	33520		64	0.188	90	64						
33	8.5	35615		68	0.177	99	65						
34				68	0.177	99	66						
35	9.0	37710	3/4"/10 blows		0.075	143	67						
36							68						

DATE: Nov. 8, 2005	REMARKS ON DRIVING CONDITIONS, PRE-BORING, ETC. (IDENTIFY BY PENET. DISTANCE.)
START DRIVING TIME: 12:30 PM	substantial refusal = 105 tons
END DRIVING TIME: 12:58 PM	
DOWN TIME:	
TOTAL DRIVING TIME: 28 min	Heat No. 51664

FORMULA USED	REQUIRED BEARING* (tons)	SCOUR EL.	AUTHORIZED PILE LENGTHS
☒ ASD ☐ LRFD $P = \frac{3.5E}{S+0.2} \times \frac{W+0.2M}{W+M}$	65.5	N.A.	A = 40'
INSPECTOR SIGNATURE: Joe Pounder, Jr.	PROJECT ENGINEERING SIGNATURE: Joe Pounder, Sr.		BRIDGE OFFICE (Initial and Date): MCS 11-8-05

* INDICATE THE "DESIGN LOAD" FOR ASD, INDICATE "R_n" FOR LRFD.

INSTRUCTIONS FOR COMPLETING
TEST PILE REPORT

Pile Data:

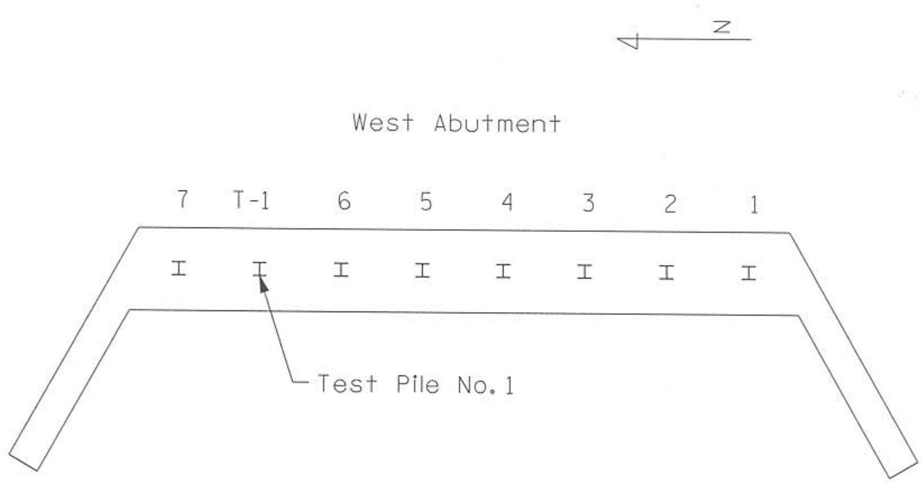
1. Check type of pile as: C.I.P., H-Pile, Treated Timber, Untreated Timber, Precast Concrete, etc.
2. Show **Size** of pile; when using timber pile show butt and tip size to the nearest one-half inch. Be certain that diameters comply with the specifications. Butt diameters should be measured 3 feet from the butt end.
3. **Length in Leads** should be total length in leads in feet.
4. Show **Weight of Pile** and **Weight of Cap** to nearest ten pounds.
5. **INSP. BY** should be the pile driving inspector (print or type name).

Column Tabulation:

6. **ENERGY PER BLOW (ft. lbs.)** is equal to WH, for single power-driven hammers. When field determination of energy output is not practical, 75% of the manufacturer's maximum rated energy may be used for computations (see Spec. 2452.3E2).
7. **BLOWS PER MIN.** need not be shown for drop hammers.
8. **PENET. PER BLOW (inches)** may be based on blows per foot or on a measured penetration for a given number of blows, and should be calculated in inches and decimals of inches.
9. **BEARING IN TONS** should be shown to the nearest ton or one-tenth of a ton.

SHOW SKETCH BELOW

Show sketch indicating location of test pile. Show North arrow.



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MnDOT TP-02210-05 (11/05)

MINNESOTA DEPARTMENT OF TRANSPORTATION

Minnesota Department of Tranportation Office of Bridges and Structures

PILE DRIVING REPORT

(English)

SEE INSTRUCTIONS ON OTHER SIDE

PILE HAMMER DATA

☐ DROP (Gravity)
☒ SINGLE ACTING (Power)
☐ DOUBLE ACTING (Power)

Make and Model: Delmag D19-42

Max. Rated Energy 42,800 (ft. lbs.)

Weight of Ram (piston) 4190 (lbs.)

Weight of Cap 1720 (lbs.)

Formula Used: ☒ ASD ☐ LRFD

Indicate Formula: $P = \frac{3.5E}{S+0.2} \times \frac{W+0.2M}{W+M}$

TYPE OF PILE (include shell wall thickness): HP 10x57

Cut-off Eevation: 789.04

Contractor: Willdrive, Inc.

PROJECT DESCRIPTION

Bridge No.: 82500

Location: TH 694 over TH 5

County: Washington Dist. Metro

S.P. (~~or S.A.P.~~) No.: SP 185-694-01

SUBSTRUCTURE

☒ Abutment N S E (W)

☐ Pier No. 1 2 3 4 or ____

1	2	3		4	5		6	7	8	9	10	11	12	13
DATE DRIVEN	PILE NO.	LENGTH (L.F.)		WEIGHT OF PILE (lbs.)	CUT-OFFS (feet)		DISTANCE BELOW CUT-OFF (feet)	FINAL ENERGY PER BLOW (ft. lbs.)	PENET. PER BLOW (inches)	BEARING IN (tons)	NET DRVG. TIME (min.)	AUTH. SPLICE	Mn/DOT CUT-OFF DRIVEN (feet)	REMARKS/REDRIVES
		FINAL AUTH.	ACTUAL TOTAL IN LEADS		ACTUAL	Mn/DOT								
				-- Test Pile --										
11-8-05	T-1	45.0	45.0	2565	11.0	11.0	34.0	37710	0.075	143	28			Heat No. 51664
			-- Foundation Piles --											
11-8-05	1	40.0	40.0	2280	7.8	7.8	32.2	35615	0.194	96				
11-8-05	2	40.0	42.0	2394	7.4	7.4	34.6	35615	0.211	92	25	1	4.6	12.0' C.O. from T.P.2
11-8-05	3	40.0	40.0	2280	7.7	7.7	32.3	35615	0.200	95	27			
11-8-05	4	40.0	40.0	2280	5.8	5.8	34.2	37710	0.207	99				
11-8-05	5	40.0	40.0	2280	3.9	3.9	36.1	37710	0.240	91				
11-8-05	6	40.0	40.0	2280	6.7	6.7	33.3	35615	0.231	88				
11-8-05	7	*35.0	35.0	1995	1.1	1.1	33.9	37710	0.182	108				*Actual short of Auth'd
		——					——							
		275.0					236.6							
		− 12.0	Cutoff				−4.6							
		═	═		═	═	═			═		═		
		263.0	277.0		40.4	40.4	232.0			669.0		1		

14. OTHER REMARKS (IDENTIFY BY PILE NO.)

SUMMARY

PLAN NUMBER AND LENGTHS: 1 T.P. @ 45', 7 F.P. @ 35'

BRIDGE OFFICE RECOMMENDED NO. AND LENGTHS: 1 T.P. @ 45', 7 F.P. @ 40'

15. AVERAGE DRIVEN LENGTH (L.F.): 33.8'

REQUIRED BEARING* (tons): 65.5

15. AVERAGE BEARING (tons): 95.5

PAY QUANTITIES

PILING DELIVERED (L.F.): 263.0

Mn/DOT CUT-OFFS DRIVEN (L.F.): 4.6

PILING DRIVEN (L.F.): 232.0

NO. OF SPLICES: 1

NO. OF REDRIVES: 0

NO. OF PILE TIP PROTECTION: 8

TEST PILES (NUMBER AND LENGTH): 1 @ 45'

INSPECTOR DURING DRIVING: Joe Pounder, Jr.

PROJ. ENGINEER'S SIGNATURE: Joe Pounder, Sr.

DATE: Nov. 8, 2005

SHEET ____ OF ____

* INDICATE THE "DESIGN LOAD" FOR ASD, INDICATE "R_n" FOR LRFD.

INSTRUCTIONS FOR COMPLETING
PILE DRIVING REPORT

General:

Field measurements to be to the nearest 0.1 ft..

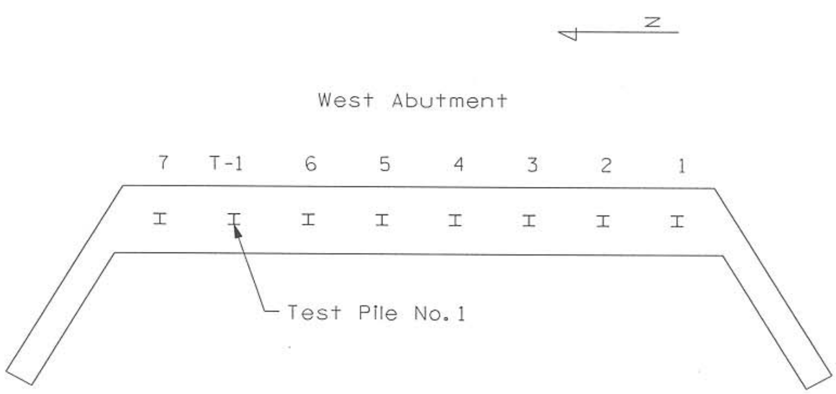
Pile Data:

(Numbers correspond with numbers on front of form)

1. **DATE DRIVEN**: Use date on which driving was completed for each pile.
2. **PILE NO.**: Show number assigned to each pile, usually the same as the driving sequence.
3. **LENGTH (ft.)** in leads:
   Final Auth.: Use final length authorized for payment. Include any authorized test pile extension which exceeds the test pile plan length. (do not include State owned cut-offs used)
   Actual Total in Leads: Use the actual total length in leads used for final driving of the pile.
4. **WEIGHT OF PILE (lbs.)**: Show computed weight to nearest ten pounds for actual total length in leads.
5. **CUT-OFFS (feet)**:
   Actual: Actual length in leads less length below cut-off for each pile.
   Mn/DOT: Final authorized length in leads plus State owned cut-off placed in leads less length below cut-off for each pile.
6. **DISTANCE BELOW CUT-OFF (feet)**: Actual length driven below cut-off.
7. **FINAL ENERGY PER BLOW (ft. lbs.)**: Energy developed during final blows for computing final bearing. For single acting power-driven hammers, the energy per blow is equal to WH. When field determination of energy output is not practical, 75% of the manufacturer's maximum rated energy may be used for computations. (see Spec. 2452.3E2)
8. **PENETRATION PER BLOW (inches)**: Calculate to three significant digits (1.25, 0.625 etc.) based on the last blows for gravity hammers and the last ten or twenty blows for power-driven hammers.
9. **BEARING IN (tons)**: Show to the nearest ton. (see Spec. 2452.3E2 "Notes")
10. **NET DRIVING TIME (min.)**: Actual time hammer is in operation driving the pile.
11. **AUTHORIZED SPLICES**: Number of splices eligible for payment. (see Spec. 2452.5)
12. **Mn/DOT CUT-OFFS DRIVEN (feet)**: Length below cut-off less final authorized length.
13. **REMARKS**: Indicate depth of jetting or preboring and diameter of auger used, hit obstruction, butt splitting, sequence of lengths used to make up actual total length in leads, butt and tip diameters for timber piles, individual lengths of State owned cut-offs used, etc.
    REDRIVES: Use date on which redriving was completed. Show bearing after redrive to the nearest ton.
14. **OTHER REMARKS**: To be used for other pertinent information.
15. **AVERAGE DRIVEN LENGTH AND BEARING**: Do not include test piles.

SHOW SKETCH BELOW

Show outline of footing, pile locations, and number assigned each pile. Show North arrow.
Indicate test piles with prefix "T". Indicate direction of batter with arrows and note amount of batter.



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Mn/DOT TP-02264-04 (11/05)

Minnesota Department of Transportation Office of Bridges and Structures

TEST PILE REPORT

(English)

SEE INSTRUCTIONS ON OTHER SIDE

PILE HAMMER DATA	PILE DATA	PROJECT DESCRIPTION
☐ DROP (Gravity)	Test Pile No: (1) 2 3 4 5 6 or ______	Bridge No.: 82500
☒ SINGLE ACTING (Power)	☐ CIP ☒ H-Pile ☐ ______	S.P. (~~or S.A.P.~~) No.: SP 185-694-01
☐ DOUBLE ACTING (Power)	Size: HP 10 x 57	County: Washington Dist. M
Make and Model: Delmag D19-42	Length in Leads (ft.): 45	
	Weight of Pile (lbs.): 2565	**SUBSTRUCTURE**
Weight of ram (piston) 4190 (lbs.)	Weight of Cap (lbs.): 1720	☒ Abutment N S E (W)
Max. Rated Energy 42,800 (ft. lbs.)	Cut-off Elev. (ft.): 789.04	☐ Pier No. 1 2 3 4 or ______

INSP. BY: Joe Pounder, Jr.	INSP. PHONE NO: 651-747-2131	CONTRACTOR: Willdrive, Inc.

DISTANCE BELOW CUT-OFF (feet)	DROP OF HAMMER OR RAM (feet)	ENERGY PER BLOW (ft. lbs.)	BLOWS PER MIN.	BLOWS PER FOOT	PENET. PER BLOW (inches)	BEARING IN TONS	DISTANCE BELOW CUT-OFF (feet)	DROP OF HAMMER OR RAM (feet)	ENERGY PER BLOW (ft. lbs.)	BLOWS PER MIN.	BLOWS PER FOOT	PENET. PER BLOW (inches)	BEARING IN TONS
5							37						
6							38						
7							39						
8							40						
9							41						
10	5.5	23045		18	0.667	76	42						
11	↓	↓		14	0.857	62	43						
12	↓	↓		16	0.750	69	44						
13	↓	↓		13	0.923	59	45						
14	↓	↓		17	0.706	73	46						
15	6	25140		21	0.571	93	47						
16	↓	↓		25	0.480	106	48						
17	↓	↓		26	0.462	109	49						
18	↓	↓		23	0.522	100	50						
19	↓	↓		23	0.522	100	51						
20	↓	↓		23	0.522	100	52						
21	↓	↓		22	0.545	97	53						
22	↓	↓		20	0.600	90	54						
23	↓	↓		19	0.632	86	55						
24				20	0.600	90	56						
25	5.5	23045		18	0.667	76	57						
26	5.5	23045		17	0.706	73	58						
27	6	25140		20	0.600	90	59						
28	7	29330		35	0.343	154	60						
29	↓	↓		41	0.293	170	61						
30	↓	↓		42	0.286	173	62						
31	↓	↓		33	0.364	149	63						
32	8	33520		64	0.188	247	64						
33	8.5	35615		68	0.176	271	65						
34	8.5	35615		68	0.176	271	66						
35	9	37710	3/4"/	10 blows	0.075	392	67						
36							68						

DATE: Nov. 8, 2005	REMARKS ON DRIVING CONDITIONS, PRE-BORING, ETC. (IDENTIFY BY PENET. DISTANCE.)
START DRIVING TIME: 12:30 PM	Drive to 340 x 1.15 = 391 tons
END DRIVING TIME: 12:58 PM	
DOWN TIME:	Heat No. 51664
TOTAL DRIVING TIME: 28 min.	

FORMULA USED	REQUIRED BEARING* (tons)	SCOUR EL.	AUTHORIZED PILE LENGTHS
☐ ASD ☒ LRFD $P = \frac{10.5E}{S+0.2} \times \frac{W+0.1M}{W+M}$	340	N.A.	A = 40'
INSPECTOR SIGNATURE: Joe Pounder, Jr.	PROJECT ENGINEERING SIGNATURE: Joe Pounder, Sr.		BRIDGE OFFICE (Initial and Date): MCS 11-8-05

* INDICATE THE "DESIGN LOAD" FOR ASD, INDICATE "R_n" FOR LRFD.

INSTRUCTIONS FOR COMPLETING
TEST PILE REPORT

Pile Data:

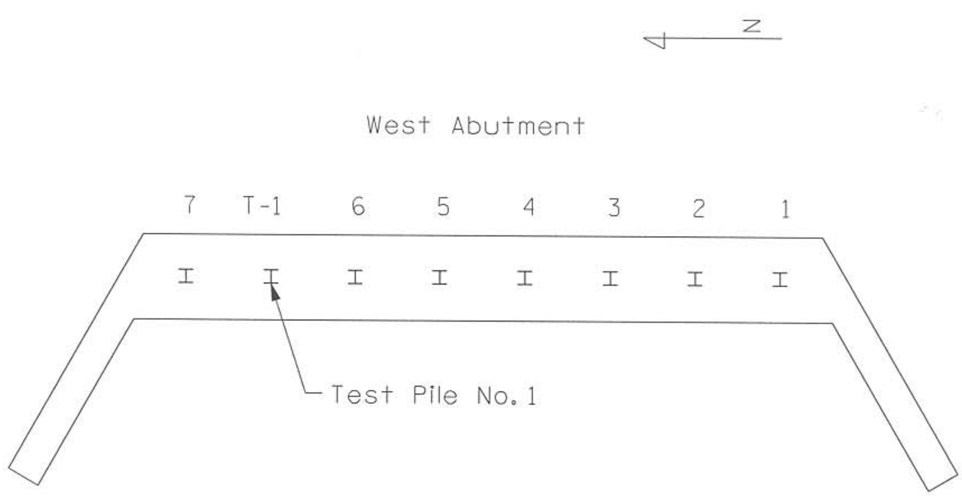
1. Check type of pile as: C.I.P., H-Pile, Treated Timber, Untreated Timber, Precast Concrete, etc.
2. Show **Size** of pile; when using timber pile show butt and tip size to the nearest one-half inch. Be certain that diameters comply with the specifications. Butt diameters should be measured 3 feet from the butt end.
3. **Length in Leads** should be total length in leads in feet.
4. Show **Weight of Pile** and **Weight of Cap** to nearest ten pounds.
5. **INSP. BY** should be the pile driving inspector (print or type name).

Column Tabulation:

6. **ENERGY PER BLOW (ft. lbs.)** is equal to WH, for single power-driven hammers. When field determination of energy output is not practical, 75% of the manufacturer's maximum rated energy may be used for computations (see Spec. 2452.3E2).
7. **BLOWS PER MIN.** need not be shown for drop hammers.
8. **PENET. PER BLOW (inches)** may be based on blows per foot or on a measured penetration for a given number of blows, and should be calculated in inches and decimals of inches.
9. **BEARING IN TONS** should be shown to the nearest ton or one-tenth of a ton.

SHOW SKETCH BELOW

Show sketch indicating location of test pile. Show North arrow.



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MnDOT TP-02210-05 (11/05)

Minnesota Department of Tranportation Office of Bridges and Structures

PILE DRIVING REPORT

(English)

SEE INSTRUCTIONS ON OTHER SIDE

PILE HAMMER DATA

☐ DROP (Gravity)
☒ SINGLE ACTING (Power)
☐ DOUBLE ACTING (Power)

Make and Model: Delmag D19-42

Max. Rated Energy 42,800 (ft. lbs.)

Weight of Ram (piston) 4190 (lbs.)

Weight of Cap 1720 (lbs.)

Formula Used: ☐ ASD ☒ LRFD

Indicate Formula:

$$P = \frac{10.5E}{S+0.2} \times \frac{W+0.1M}{W+M}$$

TYPE OF PILE (include shell wall thickness): HP 10X57

Cut-off Evevation: 789.04

Contractor: Willdrive, Inc.

PROJECT DESCRIPTION

Bridge No.: 82500

Location: TH 694 over TH 5

County: Washington Dist. Metro

S.P. (or S.A.P.) No.: SP 185-694-01

SUBSTRUCTURE

☒ Abutment N S E (W)
☐ Pier No. 1 2 3 4 or ____

1	2	3		4	5		6	7	8	9	10	11	12	13
DATE DRIVEN	PILE NO.	LENGTH (L.F.) FINAL AUTH.	ACTUAL TOTAL IN LEADS	WEIGHT OF PILE (lbs.)	CUT-OFFS (feet) ACTUAL	Mn/DOT	DISTANCE BELOW CUT-OFF (feet)	FINAL ENERGY PER BLOW (ft. lbs.)	PENET. PER BLOW (inches)	BEARING IN (tons)	NET DRVG. TIME (min.)	AUTH. SPLICE	Mn/DOT CUT-OFF DRIVEN (feet)	REMARKS/REDRIVES
				--	Test	Pile	--							
11-8-05	T-1	45.0	45.0	2565	11.0	11.0	34.0	37710	0.075	392	28			Heat No. 51664
			--	Foundation	Piles	--								
11-8-05	1	40.0	40.0	2280	7.8	7.8	32.2	35615	0.075	381				
11-8-05	2	40.0	42.0	2394	9.4	7.4	34.6	35615	0.063	394	25	1	4.6	12.0' C.O. from T.P.2
11-8-05	3	40.0	40.0	2280	7.7	7.7	32.3	35615	0.088	364	27			
11-8-05	4	40.0	40.0	2280	5.8	5.8	34.2	37710	0.088	385				
11-8-05	5	40.0	40.0	2280	3.9	3.9	36.1	37710	0.063	422				
11-8-05	6	40.0	40.0	2280	6.7	6.7	33.3	35615	0.075	381				
11-8-05	7	*35.0	35.0	1995	1.1	1.1	33.9	37710	0.088	397				*Actual less than authorized
		275.0					236.6							
		-12.0	cutoff				-4.6							
		263.0	277.0		42.4	40.4	232.0			2724				

14. OTHER REMARKS (IDENTIFY BY PILE NO.)

SUMMARY

PLAN NUMBER AND LENGTHS: 1 T.P. @ 45' 7 F.P. @ 35'

BRIDGE OFFICE RECOMMENDED NO. AND LENGTHS: 1 T.P. @ 45' 7 F.P. @ 40'

15. AVERAGE DRIVEN LENGTH (L.F.): 33.8'

REQUIRED BEARING* (tons): 340

15. AVERAGE BEARING (tons): 389.1

PAY QUANTITIES

PILING DELIVERED (L.F.): 263.0

Mn/DOT CUT-OFFS DRIVEN (L.F.): 4.6

PILING DRIVEN (L.F.): 232.0

NO. OF SPLICES: 1

NO. OF REDRIVES: 0

NO. OF PILE TIP PROTECTION: 8

TEST PILES (NUMBER AND LENGTH): 1 @ 45'

INSPECTOR DURING DRIVING: Joe Pounder, Jr.

PROJ. ENGINEER'S SIGNATURE: Joe Pounder, Sr

DATE: Nov. 8, 2005

SHEET 1 OF 1

* INDICATE THE "DESIGN LOAD" FOR ASD, INDICATE "R_n" FOR LRFD.

INSTRUCTIONS FOR COMPLETING
PILE DRIVING REPORT

General:

Field measurements to be to the nearest 0.1 ft..

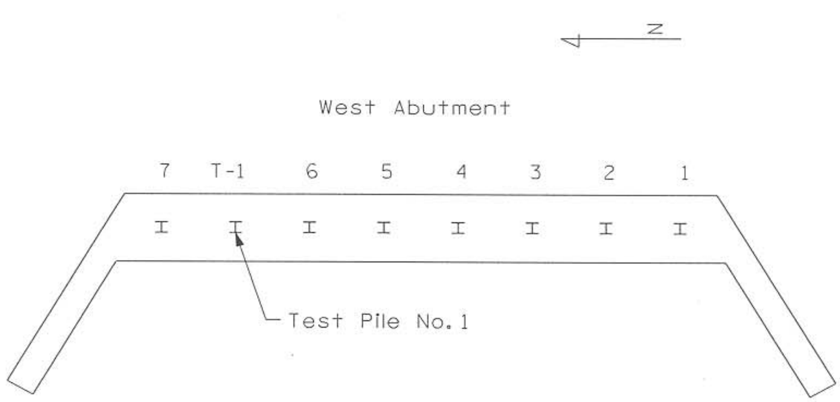
Pile Data:

(Numbers correspond with numbers on front of form)

1. **DATE DRIVEN**: Use date on which driving was completed for each pile.
2. **PILE NO.**: Show number assigned to each pile, usually the same as the driving sequence.
3. **LENGTH (ft.)** in leads:
   Final Auth.: Use final length authorized for payment. Include any authorized test pile extension which exceeds the test pile plan length. (do not include State owned cut-offs used)
   Actual Total in Leads: Use the actual total length in leads used for final driving of the pile.
4. **WEIGHT OF PILE (lbs.)**: Show computed weight to nearest ten pounds for actual total length in leads.
5. **CUT-OFFS (feet)**:
   Actual: Actual length in leads less length below cut-off for each pile.
   Mn/DOT: Final authorized length in leads plus State owned cut-off placed in leads less length below cut-off for each pile.
6. **DISTANCE BELOW CUT-OFF (feet)**: Actual length driven below cut-off.
7. **FINAL ENERGY PER BLOW (ft. lbs.)**: Energy developed during final blows for computing final bearing. For single acting power-driven hammers, the energy per blow is equal to WH. When field determination of energy output is not practical, 75% of the manufacturer's maximum rated energy may be used for computations. (see Spec. 2452.3E2)
8. **PENETRATION PER BLOW (inches)**: Calculate to three significant digits (1.25, 0.625 etc.) based on the last blows for gravity hammers and the last ten or twenty blows for power-driven hammers.
9. **BEARING IN (tons)**: Show to the nearest ton. (see Spec. 2452.3E2 "Notes")
10. **NET DRIVING TIME (min.)**: Actual time hammer is in operation driving the pile.
11. **AUTHORIZED SPLICES**: Number of splices eligible for payment. (see Spec. 2452.5)
12. **Mn/DOT CUT-OFFS DRIVEN (feet)**: Length below cut-off less final authorized length.
13. **REMARKS**: Indicate depth of jetting or preboring and diameter of auger used, hit obstruction, butt splitting, sequence of lengths used to make up actual total length in leads, butt and tip diameters for timber piles, individual lengths of State owned cut-offs used, etc.
    REDRIVES: Use date on which redriving was completed. Show bearing after redrive to the nearest ton.
14. **OTHER REMARKS**: To be used for other pertinent information.
15. **AVERAGE DRIVEN LENGTH AND BEARING**: Do not include test piles.

SHOW SKETCH BELOW

Show outline of footing, pile locations, and number assigned each pile. Show North arrow.
Indicate test piles with prefix "T". Indicate direction of batter with arrows and note amount of batter.



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FOR ALL PROJECTS:

COPY: Project Engineer
COPY: Railroad

Mn/DOT TP-02264-04 (11/05)

Minnesota Department of Transportation Office of Bridges and Structures

TEST PILE REPORT

(English)

SEE INSTRUCTIONS ON OTHER SIDE

PILE HAMMER DATA

- ☐ DROP (Gravity)
- ☒ SINGLE ACTING (Power)
- ☐ DOUBLE ACTING (Power)

Make and Model: Delmag D19-32

Weight of ram (piston) 4190 (lbs.)

Max. Rated Energy 42800 (ft. lbs.)

PILE DATA

Test Pile No. (1) 2 3 4 5 6 or______

☒ CIP ☐ H-Pile ☐ ______

Size: 12" CIP, .25 wall

Length in Leads (ft.): 50+30

Weight of Pile (lbs.): 1569/2510

Weight of Cap (lbs.): 890

Cut-off Elev. (ft.): 1005.81

PROJECT DESCRIPTION

Bridge No.: 82501

S.P. (~~or S.A.P.~~) No.: 8212-57

County: Washington Dist. M

SUBSTRUCTURE

☐ Abutment N S E W

☒ Pier No. 1 (2) 3 4 or________

INSP. BY: Joe Pounder, Jr. INSP. PHONE NO: 651-747-2131 CONTRACTOR: Willdrive, Inc

DISTANCE BELOW CUT-OFF (feet)	DROP OF HAMMER OR RAM (feet)	ENERGY PER BLOW (ft. lbs.)	BLOWS PER MIN.	BLOWS PER FOOT	PENET. PER BLOW (inches)	BEARING IN TONS
5						
6						
7						
8						
9						
10	5	20950		9	1.333	48
11	↓	↓		8	1.500	43
12	↓	↓		8	1.500	43
13	↓	↓		7	1.714	38
14	↓	↓		8	1.500	43
15	↓	↓		7	1.714	38
16	↓	↓		9	1.333	48
17	↓	↓		8	1.500	43
18	↓	↓		9	1.333	48
19	↓	↓		9	1.333	48
20	↓	↓		8	1.500	43
21	↓	↓		8	1.500	43
22	↓	↓		9	1.333	48
23	↓	↓		7	1.714	38
24	↓	↓		8	1.500	43
25	↓	↓		9	1.333	48
26	↓	↓		8	1.500	43
27	↓	↓		8	1.500	43
28	↓	↓		7	1.714	38
29	↓	↓		7	1.714	38
30	↓	↓		7	1.714	38
31	↓	↓		7	1.714	38
32	↓	↓		7	1.714	38
33	↓	↓		8	1.500	43
34				9	1.333	48
35	5.5	23045		9	1.333	53
36	5.5	23045		9	1.333	53

DISTANCE BELOW CUT-OFF (feet)	DROP OF HAMMER OR RAM (feet)	ENERGY PER BLOW (ft. lbs.)	BLOWS PER MIN.	BLOWS PER FOOT	PENET. PER BLOW (inches)	BEARING IN TONS
37	5	20950		8	1.500	43
38	5	20950		8	1.500	43
39	5	20950		8	1.500	43
40	5.5	23045		9	1.333	53
41	5.5	23045		10	1.200	58
42	5	20950		8	1.500	43
43	↓	↓		8	1.500	43
44	↓	↓		9	1.333	48
45	↓	↓		8	1.500	43
46	↓	↓		9	1.333	48
47	↓	↓		9	1.333	48
48	↓	↓		9	1.333	48
49	↓	↓		9	1.333	48
50	↓	↓	Splice	9	1.333	48
51	5.5	23045		29	0.414	118
52	5	20950		11	1.091	51
53	5.5	23045		13	0.923	64
54	5.5	23045		18	0.667	83
55	6	25140		29	0.414	128
56	6.5	27235		30	0.400	142
57	6.5	27235		35	0.343	157
58	7	29330		38	0.316	178
59	↓	↓		37	0.324	175
60	↓	↓		40	0.300	184
61	↓	↓		37	0.324	175
62	↓	↓		40	0.300	184
63	↓	↓		40	0.300	184
64	↓	↓		41	0.293	187
65	↓	↓		42	0.286	189
65 ~~66~~	9	37710	24"/	10 blows	0.225	278
~~67~~						
~~68~~	Redrove after 24 hr. Waiting period					

DATE: Nov. 8, 2005

START DRIVING TIME: 8:25 AM

END DRIVING TIME: 9:23 AM

DOWN TIME:

TOTAL DRIVING TIME: 48 min.

REMARKS ON DRIVING CONDITIONS, PRE-BORING, ETC. (IDENTIFY BY PENET. DISTANCE.)

Test pile #1 was redriven after 24 hr. Waiting period. Capacity went from 189 to 278 tons, a 47% increase. Testpile #2 was driven to 65' (176 tons) redriven after 24 hrs., Capacity went from 176 to 269 tons, a 53% increase.

FORMULA USED ☐ ASD ☒ LRFD

$$P = \frac{10.5E}{S+0.2} \times \frac{W+0.1M}{W+M}$$

REQUIRED BEARING* (tons): 241 tons

SCOUR EL.: N.A.

AUTHORIZED PILE LENGTHS: 65'

INSPECTOR SIGNATURE: Joe Pounder, Jr.

PROJECT ENGINEERING SIGNATURE: Joe Pounder, Sr.

BRIDGE OFFICE (Initial and Date): MCS 11-8-05

* INDICATE THE "DESIGN LOAD" FOR ASD, INDICATE "R_n" FOR LRFD.

INSTRUCTIONS FOR COMPLETING
TEST PILE REPORT

Pile Data:

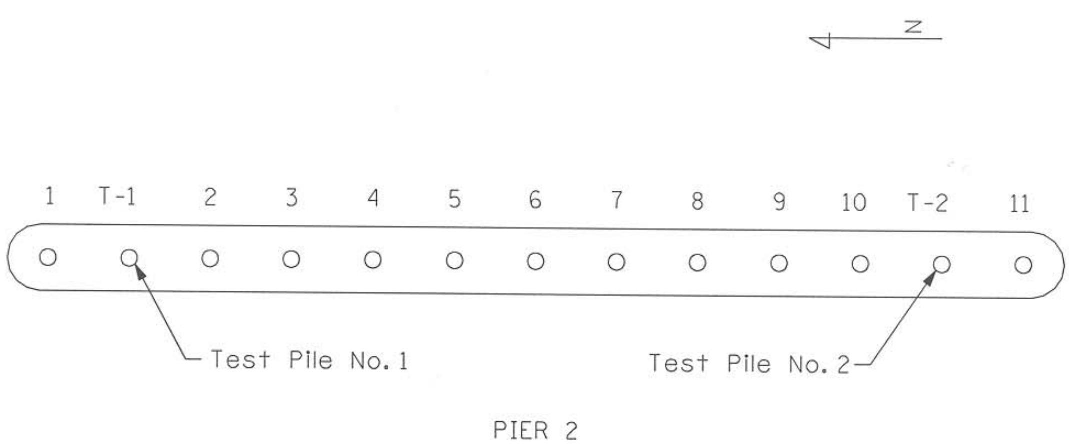
1. Check type of pile as: C.I.P., H-Pile, Treated Timber, Untreated Timber, Precast Concrete, etc.
2. Show **Size** of pile; when using timber pile show butt and tip size to the nearest one-half inch. Be certain that diameters comply with the specifications. Butt diameters should be measured 3 feet from the butt end.
3. **Length in Leads** should be total length in leads in feet.
4. Show **Weight of Pile** and **Weight of Cap** to nearest ten pounds.
5. **INSP. BY** should be the pile driving inspector (print or type name).

Column Tabulation:

6. **ENERGY PER BLOW (ft. lbs.)** is equal to WH, for single power-driven hammers. When field determination of energy output is not practical, 75% of the manufacturer's maximum rated energy may be used for computations (see Spec. 2452.3E2).
7. **BLOWS PER MIN.** need not be shown for drop hammers.
8. **PENET. PER BLOW (inches)** may be based on blows per foot or on a measured penetration for a given number of blows, and should be calculated in inches and decimals of inches.
9. **BEARING IN TONS** should be shown to the nearest ton or one-tenth of a ton.

SHOW SKETCH BELOW

Show sketch indicating location of test pile. Show North arrow.



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MnDOT TP-02210-05 (11/05)

Minnesota Department of Tranportation Office of Bridges and Structures

PILE DRIVING REPORT

(English)

SEE INSTRUCTIONS ON OTHER SIDE

PILE HAMMER DATA

- ☐ DROP (Gravity)
- ☒ SINGLE ACTING (Power)
- ☐ DOUBLE ACTING (Power)

Make and Model: Delmag D19-32

Max. Rated Energy 42,800 (ft. lbs.)

Weight of Ram (piston) 4190 (lbs.)

Weight of Cap 890 (lbs.)

Formula Used: ☐ ASD ☒ LRFD

Indicate Formula:

$$P = \frac{10.5E}{S+0.2} \times \frac{W+0.1M}{W+M}$$

TYPE OF PILE (include shell wall thickness): 12" CIP 0.25" Wall

Cut-off Evevation: 1005.81

Contractor: Willdrive, Inc.

PROJECT DESCRIPTION

Bridge No.: 82501

Location: TH 694 over TH 5

County: Washington Dist. Metro

S.P. (or S.A.P.) No.: 8212-57

SUBSTRUCTURE

☐ Abutment N S E W

☒ Pier No. 1 (2) 3 4 or ____

1 DATE DRIVEN	2 PILE NO.	3 LENGTH (L.F.) FINAL AUTH.	3 LENGTH (L.F.) ACTUAL TOTAL IN LEADS	4 WEIGHT OF PILE (lbs.)	5 CUT-OFFS (feet) ACTUAL	5 CUT-OFFS (feet) Mn/DOT	6 DISTANCE BELOW CUT-OFF (feet)	7 FINAL ENERGY PER BLOW (ft. lbs.)	8 PENET. PER BLOW (inches)	9 BEARING IN (tons)	10 NET DRVG. TIME (min.)	11 AUTH. SPLICE	12 Mn/DOT CUT-OFF DRIVEN (feet)	13 REMARKS/REDRIVES
				--	Test	Piles	--							
11-8-05	T-1	80	80	2510	15.0	15.0	65.0	29330	0.286	189	48			278 tons after 24hr.
														redrive - 47% increase
11-8-05	T-2	80	80	2510	15.0	15.0	65.0	29330	0.324	175	53			269 tons after 24 hr.
														redrive - 53% Increase
			--	Foundation	Piles	--								
11-8-05	1	65	65	2039	0	0	65.0	27235	0.286	185				268T/24hr. redrive, 45% Incr.
11-8-05	2	65	65	2039	0	0	65.0	29330	0.343	179				
11-8-05	3	65	65	2039	0	0	65.0	29330	0.308	191				
11-8-05	4	65	65	2039	0	0	65.0	29330	0.343	179	58			
11-8-05	5	65	65	2039	0	0	65.0	27235	0.324	172				270/24hr. redrive, 57% Incr.
11-8-05	6	65	65	2039	0	0	65.0	29330	0.300	194				
11-8-05	7	65	68	2133	3.0	0	65.0	29330	0.343	177				
11-9-05	8	65	65	2039	0	0	65.0	29330	0.343	179				
11-9-05	9	65	70	2196	5.0	0	65.0	29330	0.300	190	51			
11-9-05	10	65	65	2039	0	0	65.0	29330	0.333	182				
11-9-05	11	65	69	2165	4.0	0	65.0	27235	0.293	180	54			
		═	═		═	═	═			═				
		715.0	727.0		12.0	0	715.0			2008				

Avg. Brg. = 183 tons

Average increase from set-up = 51%

Average final driven bearing = 183 x 1.51 = 276 T

Four piles were redriven after 24 hrs. with capacity increases of 47%, 53%, 45% and 57%. Average capacity increase is 51%.

14. OTHER REMARKS (IDENTIFY BY PILE NO.) Non-redriven piling accepted on assumption of 51% increase in capacity after redrive. Minimum required capacity at initial drive = 241/1.51 = 160 tons. All initial drives exceeded 160 tons.

SUMMARY

PLAN NUMBER AND LENGTHS: 2 T.P. @ 80', 11 F.P. @ 65'

BRIDGE OFFICE RECOMMENDED NO. AND LENGTHS: 2 T.P. @ 80', 11 F.P. @ 65'

15. AVERAGE DRIVEN LENGTH (L.F.): 65.0'

REQUIRED BEARING* (tons): 241

15. AVERAGE BEARING (tons): 276

PAY QUANTITIES

PILING DELIVERED (L.F.): 715.0

Mn/DOT CUT-OFFS DRIVEN (L.F.): 0

PILING DRIVEN (L.F.): 715.0

NO. OF SPLICES: 0

NO. OF REDRIVES: 4

NO. OF PILE TIP PROTECTION: 0

TEST PILES (NUMBER AND LENGTH): 2 @ 80'

INSPECTOR DURING DRIVING: Joe Pounder, Jr.

PROJ. ENGINEER'S SIGNATURE: Joe Pounder, Sr.

DATE: 11-8-05

SHEET 1 OF 1

* INDICATE THE "DESIGN LOAD" FOR ASD, INDICATE "R_n" FOR LRFD.

INSTRUCTIONS FOR COMPLETING
PILE DRIVING REPORT

General:

Field measurements to be to the nearest 0.1 ft..

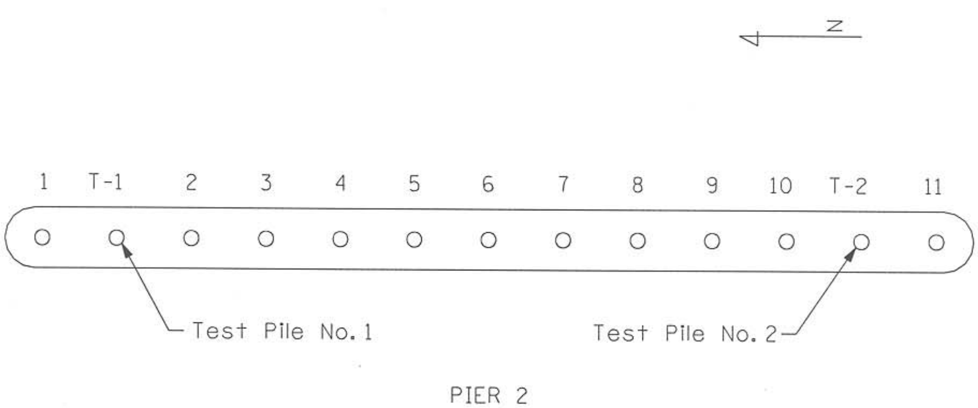
Pile Data:

(Numbers correspond with numbers on front of form)

1. **DATE DRIVEN:** Use date on which driving was completed for each pile.
2. **PILE NO.**: Show number assigned to each pile, usually the same as the driving sequence.
3. **LENGTH (ft.)** in leads:
   Final Auth.: Use final length authorized for payment. Include any authorized test pile extension which exceeds the test pile plan length. (do not include State owned cut-offs used)
   Actual Total in Leads: Use the actual total length in leads used for final driving of the pile.
4. **WEIGHT OF PILE (lbs.)**: Show computed weight to nearest ten pounds for actual total length in leads.
5. **CUT-OFFS (feet)**:
   Actual: Actual length in leads less length below cut-off for each pile.
   Mn/DOT: Final authorized length in leads plus State owned cut-off placed in leads less length below cut-off for each pile.
6. **DISTANCE BELOW CUT-OFF (feet)**: Actual length driven below cut-off.
7. **FINAL ENERGY PER BLOW (ft. lbs.)**: Energy developed during final blows for computing final bearing. For single acting power-driven hammers, the energy per blow is equal to WH. When field determination of energy output is not practical, 75% of the manufacturer's maximum rated energy may be used for computations. (see Spec. 2452.3E2)
8. **PENETRATION PER BLOW (inches)**: Calculate to three significant digits (1.25, 0.625 etc.) based on the last blows for gravity hammers and the last ten or twenty blows for power-driven hammers.
9. **BEARING IN (tons)**: Show to the nearest ton. (see Spec. 2452.3E2 "Notes")
10. **NET DRIVING TIME (min.)**: Actual time hammer is in operation driving the pile.
11. **AUTHORIZED SPLICES**: Number of splices eligible for payment. (see Spec. 2452.5)
12. **Mn/DOT CUT-OFFS DRIVEN (feet)**: Length below cut-off less final authorized length.
13. **REMARKS**: Indicate depth of jetting or preboring and diameter of auger used, hit obstruction, butt splitting, sequence of lengths used to make up actual total length in leads, butt and tip diameters for timber piles, individual lengths of State owned cut-offs used, etc.
    REDRIVES: Use date on which redriving was completed. Show bearing after redrive to the nearest ton.
14. **OTHER REMARKS**: To be used for other pertinent information.
15. **AVERAGE DRIVEN LENGTH AND BEARING**: Do not include test piles.

SHOW SKETCH BELOW

Show outline of footing, pile locations, and number assigned each pile. Show North arrow.
Indicate test piles with prefix "T". Indicate direction of batter with arrows and note amount of batter.



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Sometimes all of the requested information is not shown; this is the case especially with the column headed Net Driving Time, where driving time should be shown for at least enough piles to give representative information. Other times the entries are such as to be suspect of "manufacture" after the driving was completed. Certainly it is much better to omit an entry than to falsify one, since an entry that can be shown to be false by an attorney during a court case, could also discredit other entries. Recording the actual driving time on the reports tends to discourage claims by contractors that inspectors are requiring overdriving. The pile driving foreman is not likely to use this as an excuse for a slow operation if our records will prove otherwise. The driving time record could also be very beneficial in determining price adjustments in the event of conditions different than those which were anticipated.

The column headed Authorized Splices is intended to be used for recording those splices which are eligible for payment as defined under 2452.5B, unless otherwise noted under Remarks. The Specifications provide for payment for splices under three conditions, one of which is when it is necessary "to make up lengths longer than the length of the longest test pile shown in the Plan were authorized by the Engineer for a particular unit, and then only for any extra splices required." This would mean that if the plan required 25 m (80 foot) test piles and the Contractor had 15 m (50 foot) lengths on hand, an "extra" splice would not be required unless foundation lengths longer than 30 m (100 feet) were authorized since it would be necessary for him/her to make a splice to furnish 25 m (80 feet) lengths.

The column headed Remarks is sometimes unnecessarily filled with information that can better be shown elsewhere on the report, such as notations indicating "Batter Pile" which could readily be indicated by arrows on the sketch on the back side of the form. Also, since the "penetration per blow" is shown in a separate column, it is not necessary to note the penetration for the last 5, 10, or 20 blows under Remarks, although this information should be included somewhere on your working copy or field notes.

The Butt and Tip diameters of timber piles should be shown in the Remarks column, or may be shown in other unused columns if the Remarks column is needed for other reasons. Remember, there are definite minimum diameter requirements for timber piles in Specification 3471. The depth of jetting or preboring and the diameter of the preboring auger should also be shown.

Where there is insufficient space in the Remarks column to provide for notations, identify notes by (1), (2), etc., and place them at the end of the tabulation.

When abbreviations are used, be certain that they are standard abbreviations, or at least that they can be readily interpreted. If there is any doubt about interpretation, explain the abbreviation at the end of the tabulation. Someone may have to interpret these reports many years after they were prepared, as is often done now in the design office with reports that were prepared forty to sixty years ago, and clarity is essential.

A. Pile Redriving

As mentioned in section 5-393.160 of this manual, the resistance offered by soils while being disturbed by vibrations and displacement during pile driving may be quite different than that which will subsequently be offered against long-time static loads. Some soils will readjust after completion of driving and provide a high driving resistance after the soil has "set-up". In plastic (non-granular) soils the resistance will likely increase after a 24 hour delay, in some cases as much as 50 percent or more. Granular soils generally do not indicate large increases in resistance after similar waiting periods.

In some cases the special provisions will require the Contractor to "redrive" the test piles after a specified waiting period to determine the capacity that can be obtained by including pile set-up. Subsequently, an additional number of foundation piles may be also be designated for redriving to verify that adequate bearing capacity has been achieved.

Piles designated by the Engineer to be redriven shall have a required minimum time delay as stated in the special provisions between the initial driving and the redriving. During this time delay, no other piles shall be driven, unless authorized by the Engineer.

All redriving shall be performed using a "warm" pile hammer. Generally, applying at least 20 blows to a previously driven pile or timber mats shall warm up the hammer. Redrive hammer strikes shall generally not exceed 20 blows for each pile. Piles shall not be trimmed to the Plan cut-off elevation until the Engineer has determined the need for redriving.

No pile in any one substructure unit shall be filled with concrete until the Engineer decides that all piles in the unit have been driven to adequate bearing capacity and the pile shells have been trimmed to the cut-off elevation.

When piles have been redriven after a delay as a means of determining whether or not set-up can be expected, the pile capacity before and after the delay period should be shown on the pile reports. Generally only a small percentage (5-10 percent) of the piling in a substructure unit will be redriven. However, the average results from the piling that have been redriven will be used as acceptance criteria for the remaining piling in the unit. The inspector should therefore add a note to the pile reports indicating the average increase in capacity due to set-up, such as "Based on 4 redrives performed after a 24 hour waiting period, the average increase in capacity at the West abutment is 30 percent". This type of note is particulaily important on reports where redriving is necessary to achieve the minimum design bearing specified in the plans. Without such a note it may appear the piling were driven and accepted at bearing capacties less than required by the plans. Examples of a test pile and pile driving report that incorporate pile redrives are shown in Figures M, N & O, P 5-393.165.

5-393.166 PILE DRIVING ANALYZER

The pile driving analyzer (PDA) is a device to measure and analyze the effect of hammer impact on the pile and determine bearing capacity. Strain gauges are attached to the exposed portion of pile and electronic instruments record the strain pattern as the hammer impacts the pile. Soil resistance will affect the measurement and calibration is necessary for each site. A laptop computer is programmed to analyze the strain pattern and can give information on maximum bearing value, hammer efficiency, and possible pile damage. This equipment is best suited to projects with a very large quantity of piling or piles with very high loads. Special training is required for operation of the equipment.

For piling designed using LRFD methodology (see section 5-393.160 of this manual) the pile driving analyzer may be used in lieu of a dynamic formula to determine the ultimate bearing capacities in the field. If the special provisions require that the PDA be used to determine pile capacity, in most cases the Contractor will be required to provide the equipment and the necessary services will generally be provided by a geotechnical subconsultant. See your job specific special provisions for more information and further requirements.

5-393.167 PILE LOAD TESTS

Pile load tests are recognized as the most reliable method of determining the capacity of a pile to carry a static load. They are, however, costly and time consuming, and can only be justified when large numbers of piles are required in an area where the soils conditions are reasonably uniform, or when it is necessary or desirable to load piles much higher than their normally accepted capacity. We therefore, as a general practice, rely on dynamic formulas.

A pile load test may be required by the Contract for the purpose of justifying a design load which is higher than normally permitted for the type and size of piles specified and for ensuring adequate support from the material into which they are to be driven. Pile load tests may also be used as a means of determining the safe capacity of the pile by applying an appropriate factor of safety after the ultimate capacity has been determined.

Specification 2452.3D3 requires that a total load be applied which is not less than 200 percent of the design pile load for a Type 1 Load Test and a total load of 400 percent for a Type 2 Load Test and that the applications of the load be in increments which are defined as percent of the total load. It also provides for holding these loads for a specified period of time after a settlement of less than 250 μm (1/100 in.) during a 15 minute interval. Before proceeding with a pile load test on the basis of the requirements of 2452.3D3, review the Plans and Special Provisions to determine whether or not they contain additions to, or modifications of, the general requirements. The Type 2 Load Test was developed in accordance with procedures of the Texas Highway Department and additional information on these procedures is available in the users manual entitled "The Texas Quick-Load Method for Foundation Load Testing."

Chellis, in his book on Pile Foundations states that: "Basically, therefore, a pile load test can determine only the ultimate bearing capacity and not the settlement characteristics of the pile group." This is because settlement is related to time, and even though a pile load test is a better indicator in this respect than are any of the dynamic pile driving formulas, long time settlement must still rely on soil mechanics computations for a more reliable answer. Cohesive soils are more susceptible to long term settlement than are granular soils.

Several methods of applying load to the top of a pile have been satisfactorily used, and the method to be used for a particular load test is usually determined by the Contractor on the basis of available materials, equipment, and conditions. The most common method is providing a reaction by driving piles at locations adjacent to the pile to be load tested and connecting a reaction beam across the top of these piles, over the load test pile. A calibrated hydraulic jack of adequate capacity is then placed on the pile and the load applied in increments by jacking against the reaction beam. Calibration requirements are contained in 2452.3D3a.

Sometimes jacking is done against a load, such as a quantity of steel H-piles which will subsequently be used on the project, or against a piece of heavy equipment or other material.

Regardless of the type of reaction used, whenever load is applied to the pile by jacking, the gauges must be observed at close time intervals to ensure against any significant relaxation of load due to pile settlement or due to leakage in the jacking system.

A second method of loading is to provide a platform over the pile onto which materials (sand, concrete, steel, or any other material) can be placed in the required load increments, while the platform is supported solely by the pile. The load can also be applied by incremental filling of a water tank supported by the pile.

Pile settlement readings should be determined by the use of Ames dials furnished, placed, and read by Department personnel, and for which the Contractor is required to provide and install the necessary supports. It is essential that any posts or other supports be unaffected by the pile load test, so that reliable readings will be obtained. (Note: in handling the Ames dials, avoid releasing the plunger shaft abruptly as this is likely to bend or break the indicator needle). As a back-up for the Ames dial readings, and as a check on their support system, level readings should be taken either by instrument or by stretching a piano wire over two temporary bench marks which are free from disturbance. In this way, if anything should happen to the dials, the test can be continued by referring to the back-up system.

Form No: (a) Sheet No. ____ of ____

PILE LOAD TEST DATA

Bridge No. ____________ Unit No. ______________ Project Engr. ___________

S.P. No. ______________ Test No. ______________ Inspector _____________

Fed. No. ______________ Pile Type _____________ Contractor _____________

Pile Data:

No.	Size or Weight	Total Penetration	Final Penet./Blow	Computed Bear. in kN	Hammer Type
Test Pile ____					
* R.P. ______					
* R.P. ______					
* R.P. ______					

* (R.P. Denotes reaction piles)

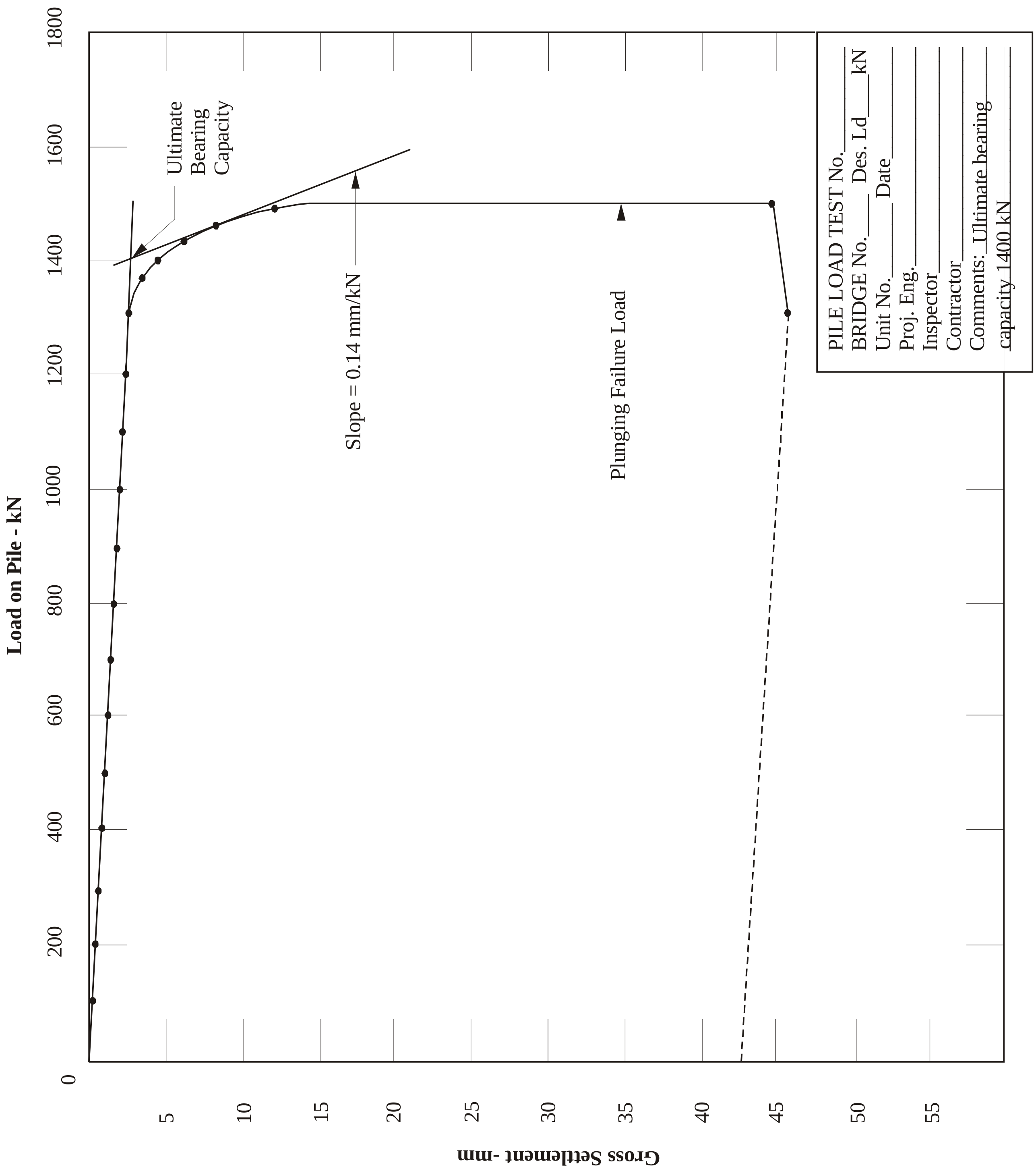
Theoretical Elastic Shortening of Pile (Neglecting skin friction) $e = \frac{P\lambda}{AE}$

Where e = deflection of head of pile
P = applied load in kN
A = cross section of pile in sq. mm
λ = length in mm
E = modulus of elasticity

Form No: (b) Sheet No. ____ of ____

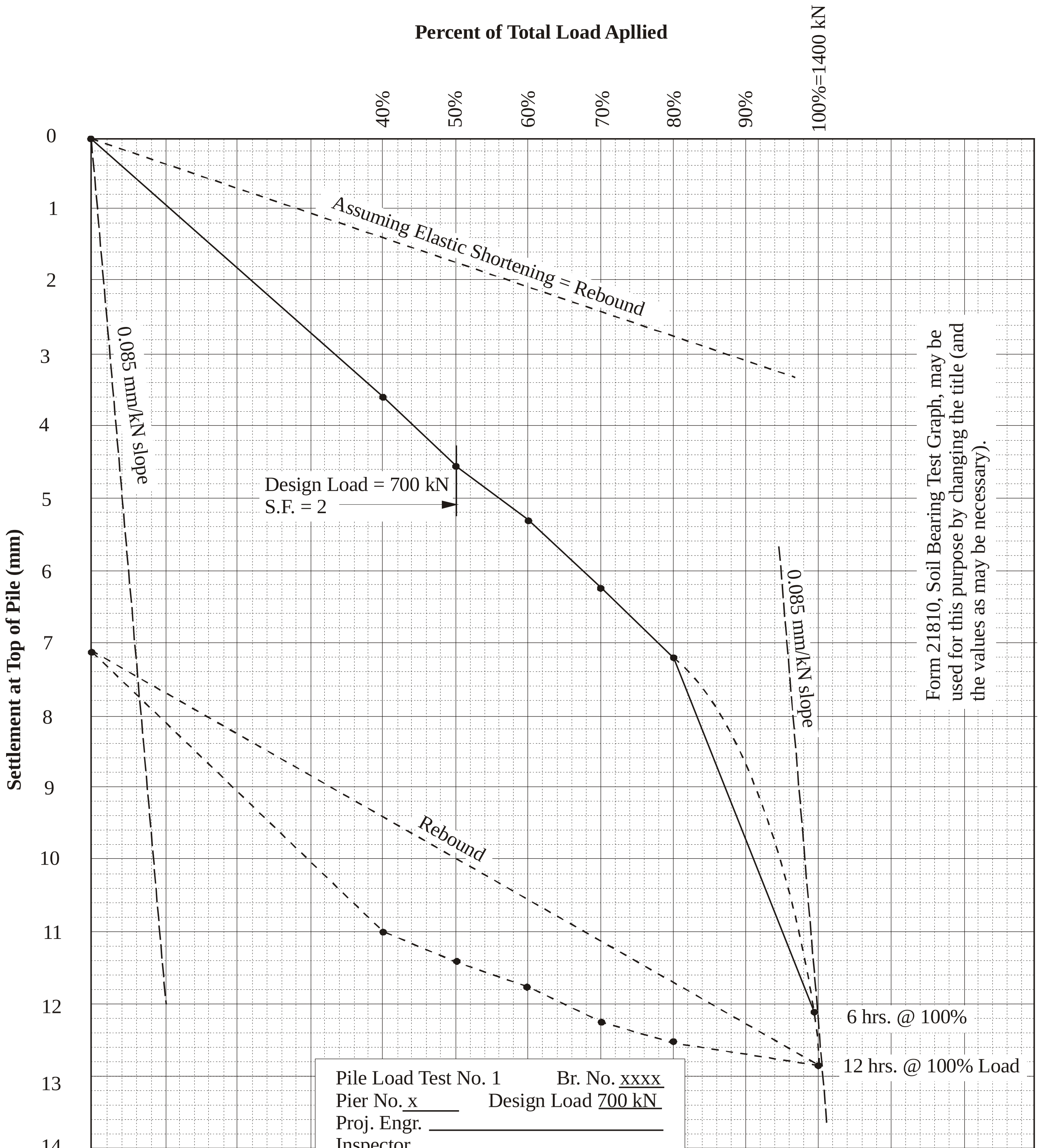
PILE LOAD TEST LOG

Date	Hour	Time Interval	Total Load Applied (kN)	Ames Dials No. 1 No. 2	Ave. Defl.	Theor. Elastic. Deform	Recorder	Remarks



EXAMPLE OF PILE LOAD TEST
TYPE 2

EXAMPLE OF
GRAPHICAL PLOTTING OF PILE LOAD TEST



Pile Load Test No. 1 Br. No. xxxx
Pier No. x Design Load 700 kN
Proj. Engr. ______
Inspector ______
Contractor ______
Comments: ______
Approaching failure @ 1400 kN
700 kN design load okay. S.F.=2
By ______ Date ______

When setting the Ames dials, the plunger shaft should be depressed very nearly the full 50 mm (2 inches) of travel, and the needle zeroed by turning the adjustment knob at the bottom of the plunger shaft. Thus, when the pile settles, the plunger shaft will extend by spring action and the amount of extension can be read directly from the face of the dial. The equipment should be protected from the sun and the weather to maintain reasonably uniform temperatures.

The reference in the Specifications to failure at 50 mm (2 inches) of settlement is only for the purpose of terminating the load test, and is not intended as an indication than the pile has not failed until that settlement is reached. The determination as to the load at which failure of the pile was reached will be made by the Engineer, in consultation with the Bridge Office based on a plotting of the results.

Pile Load Test reports should include Pile Load Test Data, Pile Load Test Log, and Graphical Plotting sheets, as shown in Figures A-C 5-393.167. If immediate determination is essential, the information may be called in to the appropriate Regional Bridge Construction Engineer in advance of preparing the reports.

5-393.168 PAYMENT FOR PILING

Test piling is paid for as plan quantity item per each pile. No deductions are made if piling is shorter than planned length. All costs of material, delivery and installation are included. Many contractors include their “fixed costs” for all pile driving in this item to ensure recovery of these costs in the event foundation pile quantities underrun. If lengths longer than shown in the plan are authorized, payment for extra length is made under items “Piling Delivered” and “Piling Driven.”

Foundation piles are paid for under two pay items. For most projects these items are “Piling Delivered” and “Piling Driven” with “Piling Driven” including all costs other than material and delivery. On some contracts the items are “Pile Placement” and “Piling Furnished and Driven” (see 5-393.153 for additional information). Quantities for “Piling Delivered” would be the total of the “Final Authorized” column on the pile driving report excluding test pile quantities. “Piling Delivered” is increased for extra test pile length authorized and decreased if the fabrication pile length in leads is less than final authorized length (see Figures C and G 5-393.165). Quantities for “Piling Driven” would be the total of the “Penetration Below Cutoff” (meters) (feet) column on the pile driving report excluding test pile quantities (adjustments for extra test pile would be added to this total). Quantities for Mn/DOT cutoffs driven and authorized splices are listed separately for payment.

5-393.169 ADJUSTMENT OF AUTHORIZED PILE LENGTHS

When a pile that is shorter than the initial authorized length is placed in the leads and is driven to required bearing (pile is accepted at less than initial authorized length), show the final authorized length equal to actual length in the leads (see Figure A 5-393.169 - pile no. 2 and Figure G 5-393.165 pile No. 1).

The Contractor should not drive beyond the authorized length without approval of the Inspector. When a pile longer than the initial authorized length is placed in the leads and is driven beyond the initial authorized length as directed by the Inspector in order to obtain required bearing,, show the final authorized length equal to the length below cut-off (see Figure A 5-393.169 - pile no. 3).

When the Inspector orders the Contractor to use Mn/DOT cut-offs, the required splices will be paid for by Mn/DOT and the following procedure is recommended. Show the final authorized length as the actual length in the leads minus the length of Mn/DOT cut-off used as noted in the "Remarks" column. Show the number of authorized splices used and the length of Mn/DOT cut-off driven. The cut-off from the pile, if any, is shown in both the actual and Mn/DOT columns (see Figure A 5-393.169 - pile no. 4).

Mn/DOT TP-02210-05 (1/00)

Minnesota Department of Transportation Office of Bridges and Structures

PILE DRIVING REPORT
(English)

SEE INSTRUCTIONS ON OTHER SIDE

PILE HAMER DATA	FORMULA USED	PROJECT DESCRIPTION
☐ DROP (Gravity) ☐ SINGLE ACTING (Power) ☐ DOUBLE ACTING (Power)		Bridge No.: Location:
Make and Model:	TYPE OF PILE (include shell wall thickness)	County: Dist. S.P. (or S.A.P.) No.:
Max. Rated Energy ____________ (ft. lbs.)		**SUBSTRUCTURE**
Weight of Ram (piston) ____________ (lbs.)	Cut-off Elevation:	☐ Abutment N S E W
Weight of Cap ____________ (lbs.)	Contractor:	☐ Pier No. 1 2 3 4 or _____

1 DATE DRIVEN	2 PILE NO.	3 LENGTH (L. F.) FINAL AUTH.	3 LENGTH (L. F.) ACTUAL TOTAL IN LEADS	4 WEIGHT OF PILE (lbs.)	5 CUT-OFFS (feet) ACTUAL	5 CUT-OFFS (feet) Mn/DOT	6 DISTANCE BELOW CUT-OFF (feet)	7 FINAL ENERGY PER BLOW (ft. lbs.)	8 PENET. PER BLOW (inches)	9 BEARING IN (tons)	10 NET DRVG. TIME (min.)	11 AUTH. SPLICE	12 Mn/DOT CUT-OFF DRIVEN (feet)	13 REMARKS / REDRIVES
	1	50	50		2.0	2.0	48							
	2	46	46		2.0	2.0	44							Less than auth'd in leads
	3	53	55		2.0	0.0	53							*F.A. add'nal 3.0 ft.
	4	45	50		2.0	2.0	48					1	3.0	5.0 ft. Mn/DOT C.O.
		194					193.0							
							- 3.0							
							190.0							

14. OTHER REMARKS (IDENTIFY BY PILE NO.) * Field Authorized

SUMMARY		PAY QUANTITIES	
PLAN NUMBER AND LENGTHS 4 @ 55'		PILING DELIVERED (L. F.) 194	Mn/DOT CUT-OFFS DRIVEN (L. F.) 3.0
BRIDGE OFFICE RECOMMENDED NO. AND LENGTHS 4 @ 50'		PILING DRIVEN (L. F.) 190	NO. OF SPLICES 1
15. AVERAGE DRIVEN LENGTH (L. F.) 48.2'		NO. OF REDRIVES	NO. OF PILE TIP PROTECTION
DESIGN BEARING (tons)	15. AVERAGE BEARING (tons)	TEST PILES (NUMBER AND LENGTH)	
INSPECTOR DURING DRIVING	PROJ. ENGINEER'S SIGNATURE	DATE:	SHEET _____ OF _____