



### 5.40.1 GENERAL

The length of piling shown on the plans is considered to be approximate only and has been determined for estimating purposes from borings and soundings.

### 5.40.2 CAST IN PLACE PILING AND STEEL PILING

The standard specifications provide that for cast in place or steel piling the contractor is entirely responsible for furnishing sufficient lengths of piling to obtain the required penetration and specified bearing. Accordingly, the standard specifications do not contain a bid item of test piling for cast in place or steel piling. Omission of the test pile and placement of responsibility for lengths on the contractor is possible because both cast in place and steel piling is supplied in uniform standard lengths and when necessary, is easily cut and spliced with only minor amounts of waste.

Although test piling is not generally used with cast in place or steel piling, a driving log of the first pile driven at each abutment or pier should be made for informational and comparative purposes only. Additional information and requirements for this log are given in [CMM 8.75](#).

### 5.40.3 TIMBER PILING

Test piling is usually specified when timber piling is used. The actual required lengths of piles are determined from the bearing information obtained from driving the test piling.

The engineer will present to the region the information obtained in driving the test piling, and based upon this information the engineer will give the contractor a written order for the number and lengths of piling to be furnished, with a copy retained in the project files.

It has been the general practice among the manufacturers and suppliers to furnish, as standard, treated timber piling in 5-foot increments of length. Other timber piling lengths, such as 12 feet, 23 feet, 36 feet, etc., are furnished at the price of the next 5 foot multiple of length, plus the cost of cutting off. Lengths of untreated timber piling are generally standardized the same as for treated piling, although some local producers may furnish untreated timber piling, in odd lengths, at unit prices applied to net lengths.

Insofar as practicable, timber piling should be ordered in 5-foot increments of length. Generally, timber piling in lengths of other multiples should not be ordered unless it is known they are available in other lengths through the contractor's supplier.

Delivery of ordered lengths of piling for timber piling will be in a single piece.

### 5.40.4 TEST PILING

Test piling is driven as an aid in determining the required or ordered length of piling. From a study of the information obtained from the soil borings and the relative location of the proposed substructure units, the number, location, and length of test piles are determined and shown on the plans. Usually, at least one test pile is driven at each substructure unit; however, in a small structure, one or two test piles may be all that is required and shown on the plans.

In order to learn of the bearing power of the subsoil, test piling is driven to a greater depth, occasionally to a penetration of 50% greater than that necessary for the required bearing for the foundation piling. Test piling is often required to be driven before the excavation for the footing. To accomplish this and to permit driving the test piling under conditions where the ground pressure is about the same as that when the foundation piling is later driven in the open excavation, the test pile is driven in an open pit or hole excavated to the elevation of the bottom of the footing. The pit should be not less than approximately 4 feet square at its excavated level. Pits for the driving of test piling are obviously not practical in large streams or areas of very unstable soils. Where difficulties are encountered, the necessary means should be provided to permit driving the test piles under conditions similar to those prevailing for the foundation piling.

The driving of test piles should be done using a cushion block equipped with new cushion material, because as the cushion material wears, high energies are transmitted to the pile head and pile hammer. This high impact energy is not an effective driving force and often results in erroneous interpretations of pile bearing capacity.

During driving of the test pile, and beginning after the pile has penetrated the upper feet of any soft or loose soil, measurements are to be taken and recorded by the inspector of the rate of penetration of the pile at each foot

interval for the total depth of penetration. The rate of penetration is the distance in inches that the pile penetrates the soil per blow of the hammer. In the case of a test pile, it must be determined by counting the number of blows of the hammer for each foot interval of penetration of the pile, and computing the rate as the average for the interval.

Per [standard spec 508.3.5.4](#) all timber test-piling cutoffs remain the property of the department until all timber piling under the contract has been driven. Upon completion of the driving, all cutoffs become the property of the contractor.

Required pile driving data is described in [CMM 8.75](#).

### 5.40.5 PILE DRIVING HAMMERS

[Standard spec 508.3.3.1](#) allows the use of gravity hammers only when permitted by the engineer. Permission could be extended for a few piles to be driven to bearing values where damage to the piling is unlikely to result from the use of gravity hammers.

[Standard spec 508.3.3](#) also establishes the minimum energy ratings for air, steam, or diesel hammers to be used on the work. The minimum energy rating is obtained by the use of a formula in [standard spec 508.3.3.3](#) but cannot be less than 7,200 foot-pounds per blow.

Hammers having the minimum required energy rating are necessary to provide sufficient energy for driving the pile to the required bearing without incurring a set or penetration per blow that is so small, that when it is used in the formula for determining the bearing power of the pile, it may give unreliable results. This conclusion is based on a study of information provided by reliable sources where records of test loading of a great number of piling shows that where the piling was driven to a set of less than 1/4 inch per blow, the bearing power of the pile as determined by formula often would have a factor of safety of less than two. The frequency of failure of the piling under test loading increased as the value of the set per blow decreased below 1/4 inch.

Manufacturers of air-, steam-, or diesel-type pile driving hammers designate each type and size of hammer by a number and the rated energy output of the hammer. This designated energy rating is usually the maximum energy the hammer is capable of producing as determined by the manufacturer by the use of formulae or by measurement of the energy developed.

[Standard spec 508.3.3.3](#) requires that the maximum energy rating furnished by the manufacturer for diesel hammers be reduced by 25% for comparison with the minimum required energy as determined by the specification formula to ascertain acceptability of the diesel hammer.

[Figure 1](#) gives information about hammers in general use by contractors on highway work in Wisconsin. The data provided includes the maximum rated energy, the length of stroke, the mass of the ram, the number of blows per minute that the hammer must deliver at the rated energy, and other information relative to the operation of the hammer. The pile hammer data is included as a matter of information and as a guide for the engineer.

[Standard spec 508.3.3.3](#) requires that the contractor must furnish authentic data applicable to the hammer proposed to be used. Other information may not be used in lieu of the required authentic data.

Some manufacturers may, for a particular hammer, list both a maximum rated energy and an average working energy. For uniformity in procedure, in determining that a hammer satisfies the specified requirements for size, the manufacturer's maximum rated energy of the hammer will be used, and if more than one energy rating is listed for a particular hammer, the higher rating will be used.

The energy output of a hammer may not, during the driving of a pile, be the same as the rated energy. For a double or differential acting air or steam hammer there should be sufficient air or steam pressure at the hammer to operate the hammer at the number of blows per minute required for a given energy rating. The energy output will vary if the delivered number of blows per minute deviates from the designated number.

For single acting air or steam hammers the energy output is a product of the weight of the ram and the length of the stroke. After an initial measurement, the inspector may assume that the ram is operating at its full stroke when the required air or steam pressure is maintained at the hammer and the hammer operates at the designated number of strokes per minute. However, the inspector should periodically measure the stroke to ensure correct hammer operation.

Diesel hammers are of two types. One type has an open upper end where the ram is unrestricted in its rebound and is visible above the body of the hammer. The height of the rebound is taken as the length of the stroke for the following blow. Under normal driving conditions, the height of rebound will increase as the resistance of the pile to driving increases. There is a force exerted on the pile by the explosion of the charge of fuel and likewise,

there is a loss in the kinetic energy developed during the fall of the ram due to the cushioning effect the explosion of the fuel has on the impact of the ram. It is reasonable to assume that the energy gain of one is about equal to the energy loss of the other, and therefore, the energy output for this type of hammer is the product of the weight of the ram and the length of stroke. Measurement of the length of stroke is made by the inspector by reading, on a graduated rod attached to and extending above the hammer body or shell, the height which the top of the ram reaches in its rebound.

For the other type of diesel hammer, the ram operates in a cylinder that is closed at the top, and the upstroke of the ram traps and compresses air in the bounce chamber, which is the space in the cylinder above the top of the ram. The energy stored in the compressed air is imparted to the ram on the downward stroke. The output energy of the hammer is designated as the equivalent energy or equivalent WH (weight x height) since it is made up of the energy produced as a product of the weight of the ram and its stroke plus the energy stored in the compressed air in the bounce chamber, which in turn is equivalent to an additional height in the fall of the hammer.

As the resistance of the pile increases, the force of explosion of the diesel fuel acting on the ram in its upstroke increases, and the increased energy of the ram increases the energy stored in the compressed air chamber that in turn provides an increase in the force imparted to the ram at the start of its downstroke. Thus, the energy output of the hammer, within the limits of its rated energy output, will increase as the resistance of the pile being driven increases.

When determining the bearing power of a driven pile, it will be necessary for the inspector, at the time of the count of the blows of the hammer and measurement of set of pile, to determine the equivalent energy of the hammer.

From a gage attached to an air hose that is connected to the bounce chamber, readings of the air pressure are made and these pressure values are converted to equivalent energy in foot-pounds per blow by means of charts prepared for the hammer and furnished with the gage.

If the resistance of the pile during the driving is sufficient to produce an air pressure in the bounce chamber, which as read from the gage and converted by chart into equivalent energy is of a value greater than the manufacturer's rated energy for the hammer, the manufacturer's rated energy for the hammer should be used in the bearing formula.

#### Example 1:

Determine the needed hammer energy rating for piles to be driven to 78,000 lbs. per pile minimum bearing.

$$P = 39 \times 2,000 = 78,000 \text{ lbs. bearing}$$

$$E = 0.15P \text{ ([standard spec 508.3.3.3](#))}$$

$$E = 0.15 \times 78,000 = 11,700 \text{ foot-pound}$$

### 5.40.6 DRIVING PILING

Before actual driving operations start, a check should be made by the inspector of the contractor's layout of the piling positions to ensure they are driven at the correct locations. After a pile has been placed in position for driving, a check should be made to determine it is plumb or has the correct batter. Determination should be made during the driving that the pile is retained in its correct position. Checking the batter of a pile may be made with a spirit level attached to a board that has one edge cut to the required pile batter.

A proper driving helmet and pile head adapter should always be used to ensure the pile head isn't damaged and the hammer is centered on the head of the pile. Upon completion of one piling unit and before driving operations in the next piling unit, it is advisable, whenever possible, to measure the distance between the units to ensure the location of the unit as originally staked is correct.

All piling, other than columnar piling or those piles that are driven to rock or other impenetrable strata, develop their bearing power largely through friction created between the surface of the pile and the soil through which it is driven. Usually, the bearing power of a pile increases with depth of penetration. To ensure that foundation piles are driven to adequate bearing, as determined by measurement of the set of the pile per blow of the hammer, foundation piles are driven after the excavation for the structure unit has been substantially completed. When pre-boring is a bid item in the contract, piling to be driven through embankments is driven in holes pre-bored through the embankment so that the required bearing for the pile may be obtained in the underlying foundation and be exclusive of any support which might otherwise be imparted to it by the embankment soil.

Piles are required to be driven to a specified bearing and to a minimum depth of penetration to provide a

satisfactory foundation for support of the structure unit. If the specified bearing value is reached and if the specified minimum penetration is reached, the pile can be considered to have adequate support and the driving can be stopped. It is often necessary to drive a pile to a greater depth than the specified minimum penetration to obtain the required bearing, and sometimes it is necessary to drive a pile to more than the required bearing in order to reach a specified minimum penetration. [Standard spec 508.3.5.3](#) provides that the minimum penetration for piling in pile bents will not be less than 10 feet below the elevation of the stream bed or original ground line, and for foundation piling not less than 10 feet below the bottom of the footings or original ground line, whichever is lower.

The minimum pile embedment is to provide lateral resistance to any pile or structure movement. The plans or special provisions may specify that piles must be driven to a greater depth of penetration in order to provide a stable foundation. This is often the case where the soil borings show satisfactory material sufficiently deep to provide the required bearing but is overlaid by a layer of soft material that may settle or flow under the loading introduced by the piling in the upper strata, resulting in a subsidence of the upper strata. Where these conditions exist, the piles must be driven until they penetrate through the soft material and into underlying firm strata.

[Standard spec 508.3.5.3](#) provides that piles may be driven to penetration depths less than the 10 feet described in the foregoing paragraph when specifically permitted by the engineer in writing.

Cohesive soils (clays and clayey silts) exhibit a property called pile-setup. As a pile is driven through these types of soils, the clay soil bonds are broken and pore water pressures develop around the pile. Over time, these bonds redevelop and pore water pressures decrease, causing a corresponding increase in frictional forces along the length of the pile. This increase in frictional forces causes the soil to adhere more tightly to the pile and to resist higher applied loads than at the completion of driving. The amount of capacity gain is dependent on soil type and length of time since driving completion. The majority of this gain occurs within 48 hours after completion of driving and can be measured by performing a re-tap on the pile with a warm pile hammer and measuring pile movement in the first 10 blows.

The contractor should exercise care when driving piling to prevent damage to the pile. Piles that break during driving are of little or no value, and may require removal and replacement or, if the break is below the ground, the driving of another pile close to it. Driving caps are required that afford some protection to the pile head against crushing by the hammer. Timber piles are required to be shaped to a close fit with the cap to preclude brooming or splitting of the pile. Where driving conditions require the piling to be driven to apparent bearing values greatly in excess of plan indicated bearing value in order to obtain the specified minimum penetration, proper methods and procedures for driving should be taken to avoid damage to the pile. Procedures may include reinforcing steel shells, metal shoes on timber piles, use of water jets, pre-boring, etc.

Under normal driving conditions, it is not considered practical to drive a timber pile, after the specified penetration has been reached, to a bearing value that exceeds the plan requirement by more than six tons.

The driving of piling after specified penetration has been obtained, to bearing values that are greatly in excess of plan requirements for the purpose of using up ordered lengths, should not be permitted.

[Standard spec 508.3.5.2](#) specifies the increment of penetration for determining the bearing must be only the average penetration or set obtained per blow during the last 5 to 10 blows of a gravity hammer, or 10 to 20 blows of other hammers. Note it is not obtained on the basis of inches per blow as generally is the case with test piling. Driving piling to be seated in rock or to be driven to refusal through even a minimum set after or just before the piling achieving refusal can result in damage to the pile.

Example 2:

Determine if final pile bearing is satisfactory.

Needed bearing = 39 tons per pile.

Needed hammer energy = 11,700 ft-lb. per blow (see example 1).

Used a Link-Belt 440 at maximum rated energy of 18,200 ft.-lb. per blow.

Actual maximum energy = 18,200 x 0.75 = 13,650 ft-lb. per blow, so hammer selection is acceptable ([standard spec 508.3.3.3](#)).

From [standard spec 508.3.5.2](#):

$$P = \frac{2E}{S + 0.2} = \frac{2(WH)}{S + 0.2}$$

Where W = 4,000 lbs (see [Figure 1](#)).      H = 4.35 ft.

S = 0.15 in. (measured average driven in last 10 blows).

$$P = \frac{2(4,000 \times 4.35)}{0.15 + 0.2} = 99,429 \text{ lbs.}$$

Final bearing is satisfactory.

The gage specified for steel shell piles is the minimum gage permitted to be furnished. When driving through adverse subsoil conditions, it is the contractor's responsibility to furnish thicker shells or provide reinforcement of shells to provide the strength and rigidity necessary for driving while remaining substantially watertight.

The contractor should coordinate the pile driving and concrete placement operations so that no damage or displacement will occur to concrete masonry in any substructure unit as a result of pile driving operations in any other unit.

To the extent practicable, all pile driving of steel shells within a substructure unit should be completed before any concrete is placed in that unit. Should it become necessary to drive piling or conduct other construction operations that might adversely affect freshly placed concrete, including blasting and demolition of existing structures within a minimum of 15 feet from the previously placed concrete, the operations should be delayed until the concrete has attained the minimum age specified for the removal of false work in [standard spec 502.3.5.2](#). This arbitrary limitation for steel shell piling should not be considered applicable to all situations, but represents what is considered adequate under normal job conditions. Under unusual or severe circumstances, the manager may invoke more stringent restrictions that in the judgment of the engineer are necessary to adequately protect the completed portions of the work.

[Figure 1](#) provides typical pile-driving hammers from various sources. Consult manufacturer's catalogs for additional hammers, later models, and other details.

#### 5.40.7 SPLICES

[Standard spec 510.3.2](#) requires that piling must be spliced by welders currently certified to the requirements of ANSI/AASHTO/AWS D1.1.

The contractor is required to designate a quality control inspector to inspect and certify that welding conforms to AWS D1.1 by completing form [DT2320](#) and submitting it to the engineer for project record.

The cost of splicing and fabricating steel pile shells or H-section piling is not paid for separately, but is incidental to the respective bid item, except as it may qualify for payment under [standard spec 510.5.1](#) or [standard spec 511.5](#).

#### 5.40.8 PILE DRIVING ANALYZER

The Case-Goble pile driving analyzer provides a method of dynamic pile testing, both for pile design and construction control. Testing is accomplished by attaching reusable strain transducers and accelerometers directly on the pile. Piles can be tested while being driven or during re-strike. The instrumentation mounted on the pile allows the measurement of force and acceleration signals for each hammer blow. This data is transmitted to a small field computer for processing and re-coded on a magnetic data tape for a permanent record. Data is also fed into an oscilloscope to observe the dynamic response of the pile to driving.

Calculations made by the computer, based upon one-dimensional wave mechanics, provide an immediate printout of maximum stresses in the pile, energy transmitted to the pile, and a prediction of the ultimate pile bearing capacity for each hammer impact. Monitoring of the force and velocity wave traces with the oscilloscope during driving also makes it possible to detect if structural pile damage has occurred. Photographs of selected

force and velocity wave traces are also made to provide additional testing documentation. The pile analyzer can be used on all types of driven piles with any impact-type pile-driving hammer.

The department presently utilizes the analyzer in an advisory capacity for evaluating if sufficient pile penetration has been achieved to develop the design capacity, if pile damage may have occurred, or if a driving system is performing satisfactorily.

#### 5.40.9 OIL FIELD PIPE

Oil field pipe may be substituted for steel HP piling unless prohibited in the contract by special provision. The minimum allowable size should be shown on the plan. Structures Design section will insert the special provision into contracts they consider unsuitable for an oil field pipe option.

Oil field pipe usually is driven open-ended. It will be necessary for the contractor to remove all water, soil, and other materials from the interior of the pipe down to the elevation of the bottom of the footing. Filling of the space is not required.

#### 5.40.10 PILE-ENCASED PIER CONSTRUCTION

The following procedure is an example of good construction practices in the construction of pile-encased piers, which are constructed without cofferdams. The contractor has the option of driving piling before excavation depending on the streambed materials. The following procedure is provided for information only and is not necessarily a contract requirement:

1. The area occupied by the pier and formwork is over-excavated a minimum of 24 inches below the bottom of pile encased pier elevation. The material excavated from the bottom of pier elevation is placed beyond the stream in accordance with the Erosion Control Implementation Plan (ECIP). This area is then partially filled with clean stone to a point approximately 6 inches below concrete grade (check with level rod to verify). Next the pre-assembled form is lowered into position. The form is properly positioned, plumbed, and secured to prevent movement during the pouring operation.
2. Six inches of clean stone is then placed inside the form to ensure that concrete cannot leak out from under the form as well as to attain the bottom pier elevation. Clean stone is also used for building up the area outside the form if building that area up is found necessary.
3. Reinforcing steel may be incorporated in the form before setting or it may be placed after the form has been set. A sufficient number of bar chairs are used to ensure that proper bar clearances are achieved.
4. Concrete can be placed through the use of a tremie, or tremies, depending upon the width and height of the pier. The movement of the tremies and recharging is limited as much as practical. Placement operations must be in accordance with [standard spec 502.3.6.3](#). When the concrete reaches an elevation that is above the water elevations, the surface is checked for any unsatisfactory materials that may have been forced upward as the concrete was being deposited. Any deleterious materials found are removed at that time from inside the form. Further concrete placement may proceed and construction technique employed to limit downstream siltation.
5. Displaced water is separated and removed from the area such that concrete particles are not discharged back into the stream.
6. After the formwork has been removed, the excavated areas are backfilled to the original streambed elevation with native material or 1 inch clean stone. In case of measurable water current, it is likely that the loose soil will be eroded away and into the stream exposing the exposed steel to the organisms. In this situation, it is recommended to use structural backfill. In other areas, it is preferred to use natural rock around bridge piers rather than structural materials.

Under no circumstances should water be used to wash out concrete forms or other equipment containing concrete be discharged into streams. The fine sediments in concrete can form a coating of the stream bottom killing mussels and other aquatic life forms.

		Max rated energy		Working weight		Ram weight		Stroke		Blow	Approx
Model No.	Type <sup>[1]</sup>	kips-ft	kN-m	kips	kN	kips	kN	ft	m	rate/ min.	Length/ ft
				0.50-10	2.2-45						
Drop hammers		Variable						Variable ‡		Very few	
<b>Vulcan Iron Works West Palm Beach, Fla. 33407</b>		Eh	Eh			Wr	Wr				
400C	SA	113.5	153.86	83	369	40	177.9	1.37	0.42	100	17
200C	DA	50.2	68.05	39	174	20	89.0	1.29	0.39	98	13
140C	DA	36.0	48.80	28	125	14	62.3	1.29	0.39	103	12
80C	DA	24.45	33.14	18	80	8	35.58	1.37	0.42	111	12
65C	DA	19.2	26.03	15	67	6.5	28.91	1.29	0.39	117	12
1-106	SA	15.0	20.33	9.7	43	5.0	22.24	3.0	0.91	60	13
7	DA	4.15	5.63	5.1	22.7	0.8	3.56	0.78	0.24	225	6
4N100	D	43.4	58.8	12.8	56.9	5.3	23.5	8.13	2.48	50-60	
1N100	D	24.6	33.4	7.6	33.8	3.0	13.3	8.13	2.48	50-60	
0	SA	24.38	33.04	16.0	71.2	7.5	33.4	3.25	0.99	50	15
<b>McKiernan-Terry Koehring-MKT Division Dover, NJ 07801</b>											
MBRS-7000	SA	361.15	489.57	161	712	88.0	391.4	4.10	1.25	40	28
OS-30	SA	90.0	122.0	50.5	225	30.0	133.4	3.0	0.91	60	21
S-20	SA	60.0	81.34	39.0	173	20.0	88.9	3.0	0.91	60	15
S-8	SA	26.0	35.25	18.3	81.4	8.0	35.6	3.25	0.99	53	14
S-5	SA	16.25	22.03	12.5	55.4	5.0	22.2	3.25	0.99	60	13
IHI-J44	D	79.4	107.63	21.5	95.6	9.7	43.2	8.17	2.49	42-70	15
DA55B	D	38.0	51.51	19.6	87.3	5.0	22.2	8.0	2.44	48	17
DE40	D	32.0	43.38	11.2	49.9	4.0	17.8	10.7	3.26	48	15
DE30	D	22.4	30.37	9.1	40.4	2.8	12.4	10.7	3.26	48	15
<b>Raymond International, Inc. 2801 South Post Road, Houston, Tex. 77027</b>											
30X	DA	75.0	107.67	52.0	231.2	30.0	133.4	2.5	0.76	70	19
5/0	SA	56.9	77.10	26.5	117.6	17.5	77.8	3.25	0.99	44	17
150C	DA	48.8	66.09	32.5	144.5	15.0	66.7	1.50	0.46	95-105	16
2/0	SA	32.5	44.06	18.8	83.4	10.0	44.05	3.25	0.99	50	15
80C	DA	24.5	33.14	17.9	79.5	8.0	35.6	1.38	0.42	95-105	12
65C	DA	19.5	26.43	14.7	65.3	6.5	28.9	1.33	0.41	110	12
1	SA	15.0	20.33	11.0	48.9	5.0	22.2	3.0	0.91	60	13
<b>The Foundation Equipment Corp. New Commerstown, Ohio 43832 (Distributor of Delmag Hammers)</b>											
D55	D	117.175†	158.84	26.3	116.9	11.9	52.8	‡		36-47	18
D44	D	87.0	117.94	22.4	99.6	9.5	42.1			37.55	16

Model No.	Type <sup>[1]</sup>	Max rated energy		Working weight		Ram weight		Stroke		Blow rate/min.	Approx Length/ft
		kips-ft	kN-m	kips	kN	kips	kN	ft	m		
				0.50-10	2.2-45						
<b>Drop hammers</b>		<b>Variable</b>						<b>Variable ‡</b>		<b>Very few</b>	
D36	D	73.78	100.02	17.8	79.1	7.9	35.3			37-53	16
D30	D	54.2	73.47	12.4	55.1	6.6	29.4			40-60	14
D22	D	39.78	53.93	11.1	49.4	4.8	21.5			40-60	14
D5	D	9.05	12.27	2.7	12.0	1.1	4.9			40-60	13
<b>Link Belt Link Belt Speeder Division, FMC Corp., Cedar Rapids, Iowa 52406</b>											
520	D	26.3	35.65	12.6	56.0	5.07	22.55	5.18	1.58	80-84	
440	D	18.2	24.67	10.3	45.8	4.0	17.79	4.35	1.39	86-90	
312	D	15.0	20.33	10.4	46.2	3.86	17.15	3.89	1.18	100-105	
180	D	8.1	10.98	4.6	20.5	1.72	7.67	4.70	1.43	90-95	
<b>L. B. Foster Co. (Distributor for Kobe Diesel Hammers) 7 Parkway Center, Pittsburgh, Pa. 15220</b>											
K150	D	281.3	381.33	80.5	358.0	33.1	147.2	8.5	2.59	45-60	28
K45	D	91.1	123.51	25.6	113.8	9.9	44.0	9.17	2.80	39-60	19
K42	D	79.0	107.09	24.0	106.7	9.26	41.2	8.5	2.59	45-60	19
K32	D	60.1	81.47	17.8	79.2	7.1	31.4	8.5	2.59	45-60	18
K25	D	50.7	68.73	13.1	58.2	5.5	24.5	9.17	2.80	39-60	18
K13	D	24.4	33.08	8.0	35.6	2.9	12.7	8.5	2.59	45-60	17
<b>Berminghammer Corp., Ltd. Hamilton, Ontario (Canada)</b>											
B500	D	75.0	101.67	16.5	73.4	6.9	30.7	12.0	3.66	40-60	
B225	D	25.0	33.89	6.8	30.2	2.9	12.7	.97	2.96	40-60	
<b>Mitsubishi International Corp. 875 North Michigan Avenue, Chicago, Ill. 60611</b>											
MB70	D	13.70	185.72	46.0	204.6	15.84	70.5	8.5	2.59	38-60	20
M43	E	84.0	113.87	22.6	100.5	9.46	42.1	8.5	2.59	40-60	16
M33	D	64.0	86.76	16.9	75.2	7.26	32.3	8.5	2.59	40-60	16
M23	D	45.0	61.00	11.2	49.8	5.06	22.5	8.5	2.59	42-60	14
M14	D	26.0	35.25	7.3	32.5	2.97	1.32	8.5	2.59	42-60	14
<sup>[1]</sup> SA = single-acting; DA = double-acting or differential acting; D = diesel. † Energy varies from maximum shown to about 60 percent of maximum depending on stroke and soil. ‡ Variable stroke; stroke = energy out/weight of ram. _ Ram weight or weight of striking part.											

Figure 1: Pile Hammer Data