Pile Alignment And Selection of Hammer

By Sidney P. Gilbert

THERE are many contributing factors involved to produce an economical and efficient pile foundation, and practical "know-how" of the contractor is a very important element for a successful pile installation. This is particularly true for alignment of piles during driving and for the selection of the most suitable pile driving hammer.

In the planning stage it is the design engineer who must apply his own knowledge and experience with that of the local contractors to produce a design on paper — the plans and the proper specifications — and in conformance with the local codes and practices. A complete knowledge of the subsurface condition is gained from exploration and the experience of the local contractor is a major contribution to the information and knowledge of the design engineer in providing the successful design of the pile foundation. Then with the cooperation of the design engineer and the inspection agency it is the responsibility of the pile driving contractor to transform that design from paper to a reality.

Besides pile alignment and the use of the proper hammer, there are several other factors which contribute to a good job. These are:

1) A clear understanding of the job specifications and the local building code.

2) A thorough study and analysis of the soil conditions as recorded in the boring logs supplied by the design engineer or soils engineer.

3) A coordination of the sequence of the piling operations with the general contractor and other subcontractors.

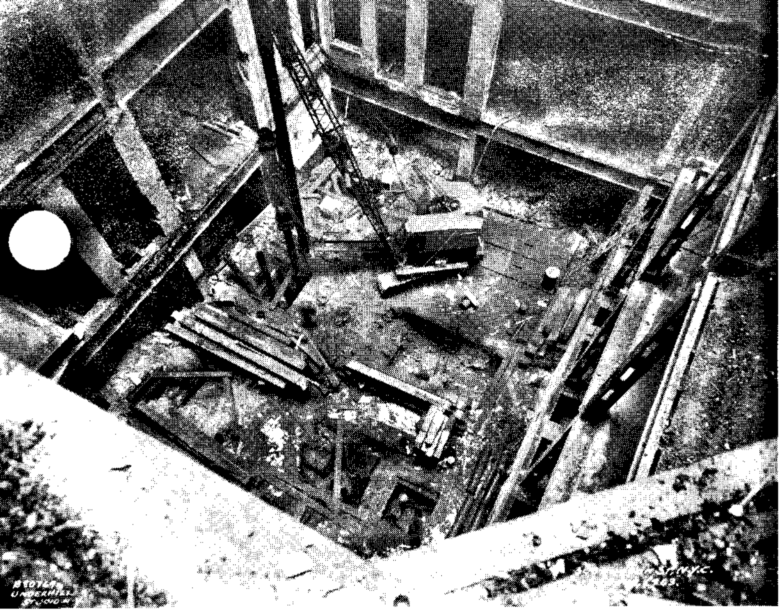
4) Proper direction of the excavator to prepare the site to accommodate the efficient movement of the pile driving rig including provision for access and egress, level travel, de-watering, sheet piling and bracing where

Sidney P. Gilbert, P.E., President
Underpinning & Foundation Co., Inc., Long Island City, N.Y.

At the present time, Mr. Gilbert's company has many foundation jobs underway all across the country from New England to San Francisco although his principal area of operation is in the New York City Metropolitan district. As the company name indicates, the scope of operations includes underpinning (lowering or supporting existing foundations, including the jacking of new piles) and many unusual, if not unique, pile installations. From these experiences, he has compiled an enviable record of success upon which he bases his belief in the importance of "practical know-how."

Among other accomplishments, he introduced the use of the Sonic Hammer in the New York area in 1963 and helped develop the famed Cobi Mandrel widely used in driving cast-in-place piles, adding to the wider choice of pile types available to the design engineer.

A native of Manhattan, Mr. Gilbert received his BSCE from the City College of New York in 1935 and is a registered Professional Engineer in New York. He is a fellow ASCE and a member of the committee studying proposed changes in the New York City Building Code. He is a member of the Moles. Following 20 years of experience in foundation construction in the New York area, in 1955 he became associated with Underpinning & Foundation Co., Inc., a firm founded and doing business since 1909; and assumed position of President of the firm in 1959.



Much practical know-how is gained by accepting the unusual assignment as well as the ordinary. Here is an example of an extremely difficult and unusual job — at the bottom of a four-sided court in a multi-storyed building. Underpinning & Foundation Company has found it pays both owner and contractor to accept such challenges.

required, and storage areas for piling.

5) The scheduling of delivery of materials and equipment to insure continuity of operations once the job is started.

PILE ALIGNMENT

1. *Use of a Solid Level Base Under the Pile Rig.* On most pile jobs the use of timber mats is required for adequate support of the rig. Only when the ground to be traversed is stable and the distances between piles considerable is it feasible to work without mats. Mats are generally made up of four pieces of 12″ x 12″ timbers 20 to 30 feet long, joined together by heavy bolts. All pile driving should be done while the rig is level, and this job is made much easier by having the rig on mats which, in turn, are on level ground. If the rig is slightly out of level this can be corrected by placing plywood strips or wood planking under one crawler or the other.

2. *Use of Fixed Leads and a Power Spotter.* Fixed leads are a very convenient means of providing good pile alignment. These types of piling driving leads are connected to the head of the boom on the crane, and at the bottom to a power spotter which in turn is secured to the base of the crane. All these connections should be fitted so that when the leads are in position for driving there will be no movement between these various parts. The power spotter permits rapid positioning of the leads at any distance generally between 20 feet and 35 feet (measured from the center pin of the crane). Once the rig is leveled no further travel is necessary to position piles within this working radius.

3. *Plumbing the Leads and Pile Prior to Driving.* Once the rig is properly leveled for driving piles in a given area it is only a matter of raising or lowering the boom and adjusting the spotter to complete "plumbing up" the leads and the pile. Plumbness of the leads and pile should be checked with a carpenter's level after the pile is set at the location where it is to be driven and after the hammer has been placed on the pile. Then the spotter can be positioned precisely to the center of the pile and the boom adjusted to position the leads vertically without being influenced by the weight of the hammer.

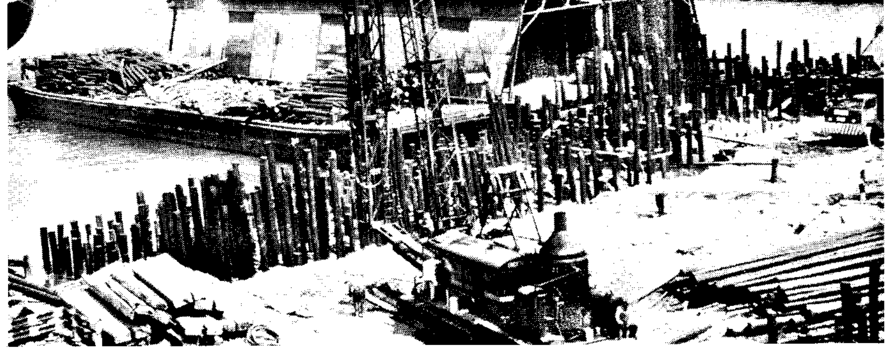
4. *Plumbing the Leads and Pile During the Driving.* As the pile is being driven it must be rechecked for plumb and for lateral movement. Incidental lateral movement (less than 3″) in the early stages of driving, is generally acceptable as long as the leads and spotter are adjusted to continue driving the pile vertically into the ground. Once substantial penetration is made, and should the pile begin to drift out of plumb, then practical judgment must be used: How to correct? Should an attempt be made to force the pile back to a plumb position by swinging or traveling aaginst it and thereby run the risk of breaking the pile? Or should the driving be continued by "following" the pile down; that is to allow the pile to seek its own course into the ground? The latter approach may often result in pile drifts out of location, but lessens the jeopardy of a broken or bent pile. Driving bowed piles — long piles that bow in the leads — present special problems. Where possible the side of the leads should be held against the bow in the pile to prevent additional deflection due to the driving. Otherwise, it is necessary to secure a cable from the rig around the front of the leads at the midpoint of the bow. During this critical stage of driving, the hammer should be operated at a slow speed to minimize the whipping action of the pile. As the pile is driven into the ground it is necessary to reset the cable around the pile until enough penetration has been accomplished and the corrective measures are no longer necessary.

5. *Batter Piles.* Driving batter piles requires close control of the rig movement on the job. Just as for plumb piles, all driving should be done with a level rig. The pile batter is produced by adjusting the leads and the spotter to the combination that produces the batter required. This can be measured by means of a carpenter's level and a template (made from plywood) cut to the indicated batter set against the inclined leads. When the leads are at the proper angle the carpenter's level will show the front face of the template to be plumb. Access to driving batter piles should be from a direction parallel to or at right angles to the plane of batter. If it is not possible to set the crane in such a position it may be necessary to mount a "moonbeam" attachment between the spotter and the bottom of the leads. The moonbeam permits lateral motion of the bottom of the leads and can produce batters when normal access to the pile location is not feasible.

HAMMER SELECTION

The selection of hammer by ram weight and rated energy, should provide the maximum capacities, generally, that when used will not damage the piles. The selection of hammers is dictated in some codes for specific types of piles and loadings. There are many codes in force today and each one has its own basis for determining the type of pile, hammer and pile capacity to be used under a certain set of conditions. So it is essential to restrict the type of hammer selected for a job to only those specifically permitted by code. In connection with these restrictions, specifications often further limit the hammer options that the contractors

Driving more than 2,500 timber foundation piles for new waterfront facilities at the East River in Brooklyn presented problems in pile alignment and hammer selection which were solved by a combination of the contractor's practical know-how and his thorough knowledge of soil conditions in the area.



may have. The following is an enumeration and description of the performance characteristics of the hammer commonly in use today.

SINGLE ACTING HAMMERS

Single acting hammers are very popular because of the simplicity of design and dependability in service. The energy of impact is derived from the gravity fall of the ram after being raised by steam or air. These hammers can be used for all soil conditions, but are more effective in penetrating heavy clays. An objection can be the slow driving rate of 50 to 70 blows per minute, but there are many pile driving situations where this is not a handicap. For timber piles the practical ranges for ram weights are between 3,000 and 6,500 pounds and energy ratings of 7,500 to 20,000 ft.-lbs.

DOUBLE-ACTING AND DIFFERENTIAL HAMMERS

Double-acting hammers deliver from 90 to 150 blows per minute. The differential hammers have a very similar speed range. This high bpm keeps the once started pile in motion and greatly speeds penetration by overcoming soil friction during the driving. These hammers work best in sandy soil but also perform well in both sand and clay.

Manufacturers of double-acting and differential hammers offer a wide choice in models and sizes with weight of ram ranging from less than 1,000 lbs. to more than 5,000 lbs. Practical rated hammer energies in ft.-lbs. run from just over 5,000 to about 20,000. Double-acting hammers have an advantage over differential hammers since the ram is completely enclosed. Thus they can be used to drive piles under water. We have found (by experience) that the differential acting hammers are the most effective type for driving timber piles in the New York Metropolitan area. The operating speed of these hammers provides double the number of blows per minute than single acting hammers and the motion imparted to the pile as a result of the rapid blows further assists the quick and satisfactory completion of the driving.

DROP HAMMERS

Before discussing the most modern hammers — the sonic or resonant, the vibratory and the diesel — the "drop hammer" should be mentioned. It is obsolete and uneconomical principally because of its extremely slow blow count of one to four per minute, which means, in comparison to modern equipment, it takes 15 times longer to drive a single pile. This is readily seen by its simple mechanic of using a line to raise its heavy ram to a great height where it is tripped into a long free fall. The operation is laboriously repeated for each blow on the pile head. Also, it is more likely to cause brooming unless the pile is adequately strapped.

DIESEL HAMMERS

The diesel hammer, a self-contained unit, is relatively new on the scene. It is universally used and as the existing building codes are modernized even greater acceptance of this new tool will result. Consisting of a cylinder, ram, anvil block and simple fuel injection system, it is basically a one cylinder, two cycle diesel engine in which the piston is actually the ram of the hammer. It starts much like the old-fashioned drop hammer by a line lifting the engine-ram to a trip which drops it. Actuated by the falling ram, a fuel metering pump injects fuel into the cylinder. Most diesel hammers are made to ignite atomized fuel on impact which in turn drives the engine back up to the trip where it drops again. The range of blows per minute is 48 to

Table S407.1C

B. For Timber Piles

Pile Capacity (tons)	Min. Driving Resistance (Blows per inch) to be added to driving resistance exerted by non-bearing materials(1)(2)	Hammer Energy (Ft.-Lbs.)(3)
Up to 20 tons	2	7,500-12,000
25 tons	3-1/2 2-1/2	9,000-12,000 14,000-16,000
30	4	12,000-16,000 (single acting hammers) 15,000-20,000 (double acting hammers)
Greater than 30		

(1) Capacities of piles in shaded area of table to be verified in accordance with the provisions of paragraph S407.1c(2).
(2) The driving resistance exerted by non-bearing materials is the resistance experienced by the pile during driving, but which will be dissipated with time and may be approximated as described in paragraph S407.1c(1)(a).
(3) The hammer energy indicated is the rated energy.

As a long-time member of the Metropolitan Section of the Committee studying proposed changes in the New York Building Code, Sidney P. Gilbert volunteered to develop a tabular relation between pile type and capacity, soil conditions, and driving resistance predicated on local experience. His suggestion was eagerly accepted and the table approved by the Committee. The section of the table as related to timber piles is shown here.

105. Ram weights run from just over 1,000 lbs. to 3,855. Rated striking energies are between 7,500 and 32,000 ft.-lbs.

There are some very good reasons for using this type of hammer: it eliminates the need for auxiliary power such as steam boiler or air compressor, it is light weight and it is economical to operate. However, it is at a disadvantage in soft driving because the ram may not rebound sufficiently to repeat its stroke thus making it necessary for the operator to raise it by the crane line up to the trip to start all over again; and another disadvantage — rated energy may be questioned.

The following hammers are now used for certain types of pile installations. These will in the near future be adapted to a broader use and may include the installation of timber piles.

Typical Diesel Hammers Used On Wood Piles

Make	Model	Rated Energy Ft. Lb.	Blows Per Minute	Weight of Ram in Lb.
Link-Belt	105	Up to 7,500	90-98	1,445
Delmag	D-5	Up to 9,100	50-60	1,100
McK-Ter	DE-20	12,000-16,000	48-52	2,000
Link-Belt	312	Up to 18,000	100-105	3,855
McK-Ter	DE-30	16,800-22,400	48-52	2,800
Delmag	D-12	Up to 22,500	50-60	2,750

Typical Air and Steam Hammers Used to Drive Wood Piling

Make	Model	Type	Rated Hammer Energy Ft. - lb.	Blows Per Minute	Weight of Ram in Lb.
Union	2	double	5,755	145	1,025
Vulcan	2	single	7,260	70	3,000
Supr-Vul	30C	diffrn	7,260	133	3,000
Union	1-1/2A	double	8,680	125	1,500
McK-Ter	9B3	double	8,750	145	1,600
McK-Ter	S3	single	9,000	65	3,000
Union	1A	double	10,020	120	1,600
McK-Ter	10B3	double	13,100	105	3,000
Union	1	double	13,100	130	1,850
Vulcan	1	single	15,000	60	5,000
Supr-Vul	50C	diffrn	15,100	120	5,000
McK-Ter	C5	double	16,000	110	5,000
McK-Ter	S5	single	16,250	60	5,000
McK-Ter	11B3	double	19,150	95	5,000
Supr-Vul	65C	diffrn	19,200	117	6,500

SONIC HAMMER

The "Sonic Hammer" invented by A. G. Bodine, Jr., consists of a series of eccentric weights oscillated in such a manner that they add their energy impulse in a vertical direction while cancelling their impulse in all other directions. These weights are oscillated by a single or multiple set up of engines mounted on a frame connected to the driver. The driver or hammer is connected to the pile by a hydraulic clamp and the pile is oscillated to its resonant frequency. To resonate a pile requires a machine that will produce 60-150 cycles per second. This rapid frequency of oscillation causes a standing wave to be established in the pile which nullifies any skin friction.

Where time is a vital factor, it is probably the most effective hammer, inasmuch as over 90 percent of its energy goes into the pile while the more conventional impact hammer delivers only 50 percent. The Sonic Hammer performs at its best in sandy soils and when driving a pile longer than 40′ but will accommodate a shorter pile if a follower is used to give it the same effective length.

VIBRATORY HAMMER

Vibratory hammers, although technically including the sonic driver, are really another breed. The vibratory hammer also has only recently been introduced into this country. It vibrates the pile — literally raising it and lowering it at the rate of 16 to 24 cycles per second, roughly the resonant frequency of sand. Depending upon low frequency longitudinal vibrations of proper amplitudes and frequency, the vibrations overcome friction and tend to fluidize the soil around the pile as it moves downward causing the soil to behave as a viscous material. We have found it most efficient in water-bearing sandy soils. Like the sonic driver, the pile must be hydraulically clamped to the vibratory hammer. It should be noted that the author does not have any knowledge of the practical application of the use of the vibratory or sonic hammer in the driving of timber piles to date.

CONCLUSIONS

1. Know the pile specifications for the job.
2. Study sections of the local building code relating to pile driving. Most codes have requisites for hammer weights and energies. A misinterpretation can result in costly redesign and delays.
3. Carefully review the soil borings before starting the operation or selection of equipment to handle the job.
4. Provide a firm and level base for the rig and plumb leads for proper pile alignment.
5. A good pile driving contractor, besides having plenty of know-how on the job, should also have a certain amount of inventive ability and be ready and able (equipped) to improvise equipment where and when it is needed to achieve a successful and economical pile installation.

Whereas pile alignment is strictly a problem for the contractor, the choice of a hammer often involves both the contractor and the designer. Selection of the proper hammer for the job and maintaining good pile alignment will avoid conditions which could be costly to both the owner and the pile contractor.

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