MODERN PILING PRACTICE

ROLT HAMMOND

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FOREWORD

ANYONE who attempts to review piling practice adequately is a super-optimist, for he can never be truly objective; he tends to concentrate upon those systems and ideas of which he himself has had practical experience, and I plead guilty to doing just that!

The great objectives to be aimed at in all piling work are Safety, Economy and Time, but the greatest of these is Safety. Yet the latter obviously is closely linked with the other two requirements. The precast and prestressed concrete pile enthusiast will claim that every inch of his pile can be inspected whilst it is being made, and, if it should not arrive at the specified set, this will be at once revealed during driving. If this type of pile has successfully passed the twin tests of handling and driving, then it is very likely to bear the static load placed upon it, which will generally be considerably less than that for which it was designed. Once driven, a pile cannot be damaged by the driving of subsequent piles, causing vibration, compression or creep in the surrounding ground.

The cast-in-place man will point out that he first drives a shell into the ground, inspects this thoroughly after it has been driven to a specified set, and makes absolutely certain that this is free from any defect before the concrete core is cast into it. The driving shock comes entirely upon this shell and not upon the pile, which therefore cannot suffer any damage from driving. In other words, the load-carrying capacity of the pile is the same as that indicated by the driving of the shell.

In some cast-in-place systems, the concrete is forced into the shell under pressure, with the result that no cavities can form therein, and the concrete will probably be forced out into a bulb foot at the base. This fact can easily be checked by simply measuring the volume of concrete poured into the ground. This bulb foot, as well as any projections along the shaft of the pile, will add very considerably to its load-carrying capacity, and thus provide an additional factor of safety.

It would certainly appear that if we can assume perfect supervision, perfect workmanship and perfect raw materials, the precast pile advocate wins every time, until we consider carefully the behaviour of the pile during driving. There must always be the possibility that a pile may break below ground during driving, and unfortunately such a fracture may take some time to develop.

A set is always obtained by a succession of blows, generally ten, and during these last ten blows a very careful watch is kept on the behaviour of the pile, and indeed this should be done with the utmost care. Therefore, although it is clearly impossible to guarantee that underground damage to a pile will not occur during the final driving without being noticed, the chances of such a thing happening are somewhat remote. Should damage be evident in the early stages of driving, it will most certainly be aggravated by succeeding blows of the hammer, and therefore it cannot fail to be apparent.

Turning now to consider the cast-in-place pile, if we make the same assumptions as we have already made in the case of the driven pile, there is the possibility that the reinforcement and the concrete pouring may be badly done; even so, precautions can be taken to ensure that the reinforcement will not be displaced and that the poured concrete will be prepared and placed in the best manner possible. We can be reasonably certain that the concrete will be dense and free from cavities, more particularly where it has been rammed. Yet we must bear in mind that here we have conditions in which the placing of the reinforcement and the pouring of the concrete are carried out under difficulties which may prevent adequate inspection both during and after pouring of the concrete.

It can be claimed on behalf of the modern precast concrete pile that it can be driven within about two days of its manufacture if rapid-hardening cement be used in its composition, or it can be obtained from stock ready made by a manufacturer of long experience, who is well equipped with all the latest machinery and who also has a modern testing laboratory. On the other hand, a cast-in-place pile can be driven at once and does not suffer from the delay of test piling. It also has the undisputed advantage that its length can be varied to suit the site or the subsoil, for the cast-in-place pile is always precisely the right length and does not require any wasteful cutting, which may have to be done in the case of a precast pile which is too long.

The paramount reason for the introduction of the cast-in-place pile has been the saving of cost and time that it has effected over the precast pile. This will obviously vary according to the range of pile length required, because there are many sites on which it is quite reasonable to assume that the length of the piles will not vary by more than a foot or two over the area. Two or three test piles will be quite sufficient to determine the length of possibly thousands of piles, in which case the best policy will probably be to adopt a precast or prestressed concrete pile.

Conversely, there are many sites where the length of piles varies widely, and this variation may be indicated by test borings or by local information gleaned from other piling work or foundations in the district. The cast-in-place pile is in its element where it is a case of getting on to a site, driving a few piles, and getting off again without the need for wasting any time in driving test piles. Yet possibly the most important development in cast-in-place piling has been the evolution of highly specialised equipment for undertaking the work, such as leaders suspended from derrick cranes or mounted on excavators specially modified for the job.

Finally, there is the question of vibration due to piling and its effect on nearby structures. Here it is relevant to point out that human beings are extremely sensitive to ground vibrations, so that what may appear to be considerable movements of the ground may in practice turn out to be practically insignificant as far as structural damage is concerned. There are certainly some cast-in-place piling systems in which there is practically no vibration, and many instances can be quoted where these have been employed close to valuable existing buildings without in any way harming them. In this respect the precast pile cannot possibly compete with the cast-in-place variety.

Let us never forget, however, that the precast pile has the great merit of simplicity, and it is certainly not obsolete. In this book I have quoted the remarkable piling work undertaken at Milford Haven in connexion with the new Marine Terminal, which is likely to arouse world-wide interest for a long time to come.

ROLT HAMMOND,
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CONTENTS

CHAPTER I

Pile-Driving Equipment

WHEN considering pile-driving equipment, it is vitally important to bear in mind that the successful conduct of a contract is often the result of using the most suitable plant, which applies with particular emphasis to marine structures.

The designer of any permanent work should therefore devote careful study to the piling methods and equipment to be employed, because very often a slight change of design may enable standard equipment to be used instead of much more expensive special plant. These and other factors will depend upon the following information being available. Full drawings and details of the proposed work; type, section and length of piles to be driven; type of ground and depth of penetration required; working load and desired ultimate resistance; and a full description of site conditions, including high and low water levels. If cranes are used for pitching the piles and for driving them, the lifting capacity, reach and boom length must be given.

Bearing piles of timber, concrete and steel are generally driven with maximum ease and economy by using a complete piling plant. This comprises a fixed vertical pile frame or a raking pile frame equipped with a steam hammer and a steam-operated winch. Driving may equally well be carried out with a drop hammer or with a diesel hammer, the winch being driven by an electric motor, a petrol engine or a diesel engine (figure 1). A single-acting hammer is generally preferred for driving bearing piles, but under certain conditions a McKiernan-Terry double-acting hammer may be preferable. Steam equipment can be equally well operated by compressed air when an adequate supply is readily available (figure 2).

An outstanding recent technical advance is the B.S.P. hydraulically operated pile-driving plant, a plan of which is shown in figure 3. This equipment is of light weight and easy to assemble; the winch and all motions, including raking, rotating, leader adjustment and travelling, are hydraulically operated. Welded construction has been used throughout for the frame, apart from bolted connexions between the large yet convenient sections into which the plant is dismantled. The leaders are tubular and the base is of box form.

This plant has been designed for an automatic hammer weighing 4 tons and a pile having a maximum weight of 6 tons. The overall height of the pile frame from ground level to the top of the head unit is about 67 feet, and the maximum length of pile that may be pitched from ground level under the hammer is about 50 feet according to the type of hammer. The standardised tubular leader units are suitable for incorporation in frames up to a maximum height of 90 feet.

The leader unit is triangular in form, with three main longitudinal tubes having an external diameter of 6½ inches equally spaced at 2 feet 9 inches centres with suitable horizontal and inclined tubular bracing. The two front tubes serve as the guide members for the hammer which is fitted with resiliently mounted back guides. The basic unit has a length of 19 feet, and three such units with the back strut unit, the head sheave unit, the bottom swivel unit and

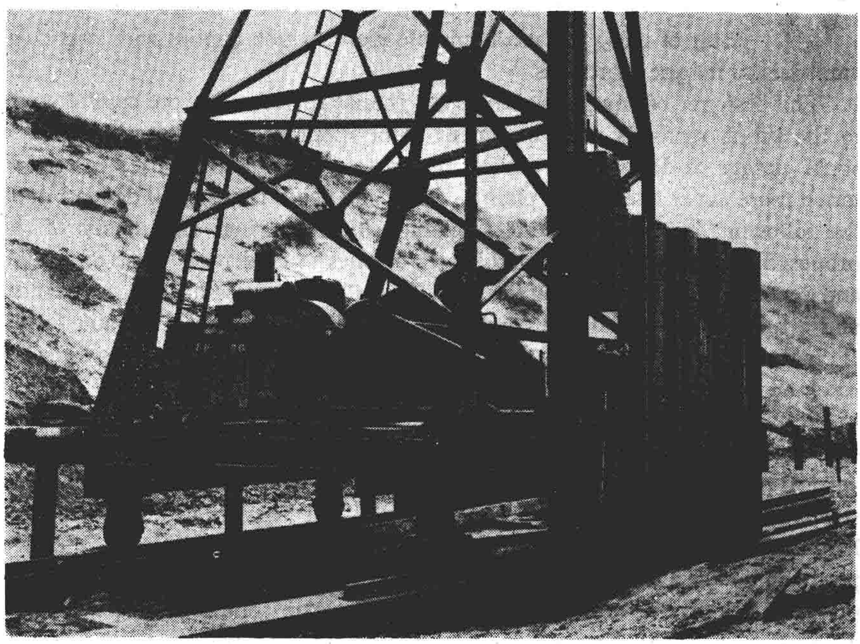

FIG. 1. Drop hammer piling rig for driving steel sheet piling, showing petrol-driven winch and helmet for head of pile. *(By courtesy of John Laing & Son Ltd.)*

the lower leader extensions are coupled to form the full height of the pile frame. The base of this consists mainly of two circular box section rings with an external diameter of 15 feet 8 inches, resting one on top of the other. The frame structure and machinery are carried by the upper ring, designed to rotate on the lower ring; rotation is achieved by power from an hydraulic motor driving a sprocket engaging with a chain fixed to the circumference of the lower ring.

The lower base ring rests on the ground, but four pairs of hydraulic jacks acting on ground bearing plates and mounted on the upper base ring are provided to level the plant when in operation. The two front pairs, disposed on each side of the leaders, operate together from one valve; the two rear pairs, one under each back strut, operate independently.

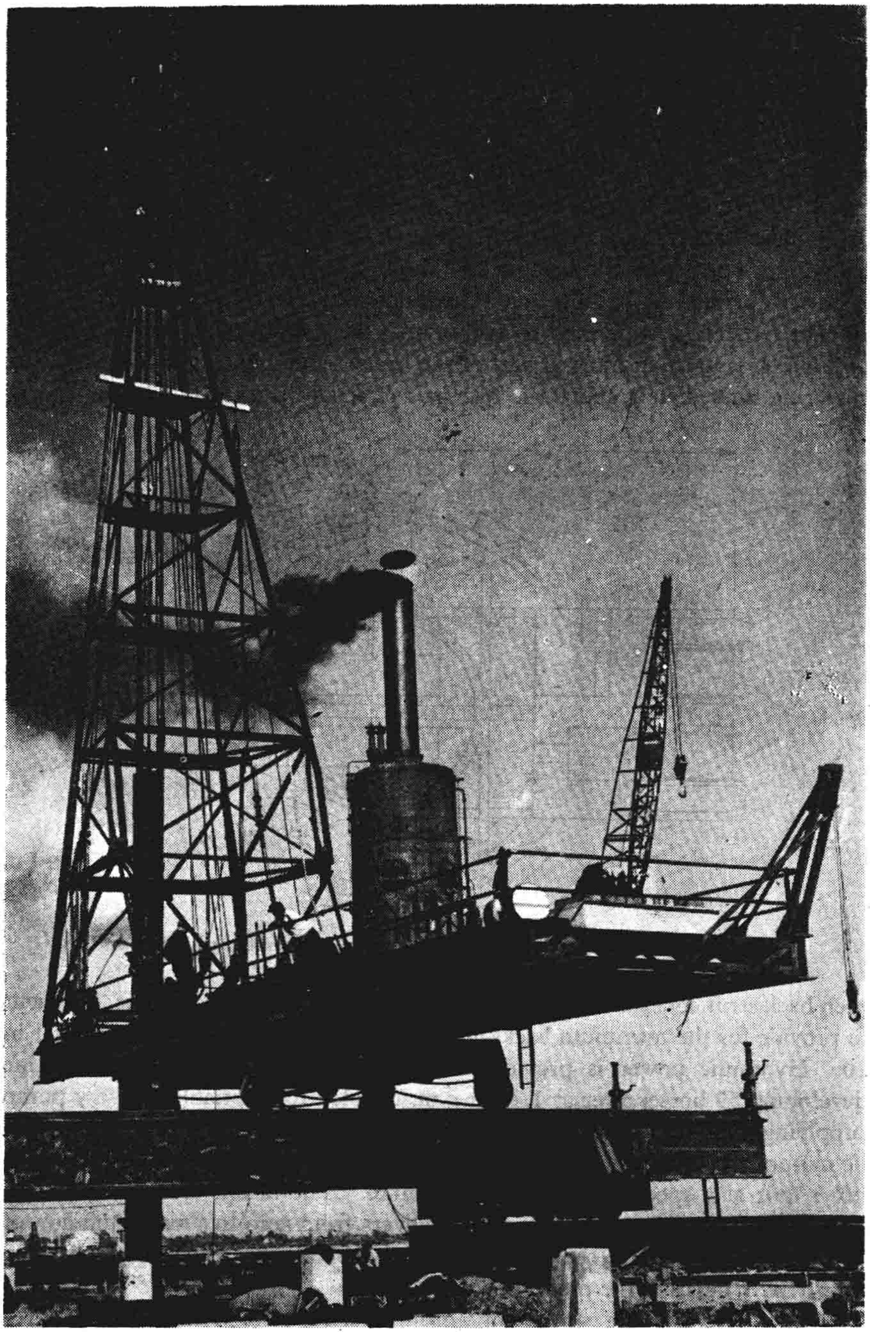

FIG. 2. A steam pile driver in use on the construction of the Marine Terminal, Fawley Refinery. (*An Esso photograph*)

Movement of the plant is effected by an ingenious hydraulic walking gear carried on an inner ring concentric with and fixed to the upper base ring. This gear consists of two hydraulic jacks, hinged to the upper base ring and to a baseplate through which pressure can be applied to the ground. Operation of the jacks tends to lift both base rings, at the same time applying a horizontal force to move the plant forward. The walking gear may be set in any desired direction of travel. When the plant is in operation, the walking gear is retracted within the base. The leader foot is pinned to a slipper mounted at the foot of the upper base ring. The slipper provides for an 'in-and-out' adjustment of 12 inches and is power operated by two horizontal hydraulic jacks.

The leaders are supported by two tubular back struts connected to a special unit which is itself an integral part of the leader assembly and is carried on the base ring immediately above the rear pair of steady jacks. The upper end of

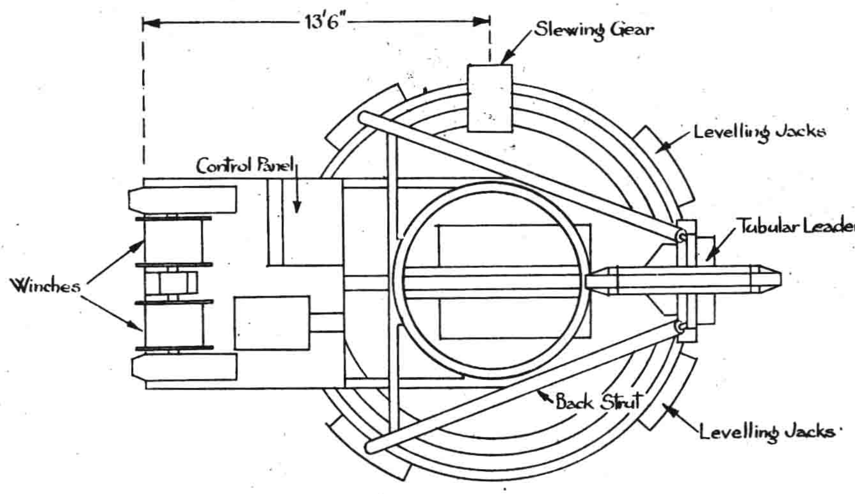

FIG. 3. General arrangement of hydraulically operated piling plant

each back strut consists of an hydraulic ram with a stroke of 55 inches, sufficient to provide for the maximum backward rake of 1 in 3 and a forward rake of 1 in 10. Hydraulic power is provided by a Fordson six-cylinder diesel engine developing 59 horsepower at 1,450 r.p.m. coupled to a variable delivery pump supplying hydraulic fluid to the various rams and motors, including the hydraulic motors driving the winch units. Each of the two winch drums is designed to lift 3 tons at a speed of 100 feet per minute. The drums are reversible and self-sustaining. The hydraulic pump delivers from zero to a maximum flow of 72·5 gallons per minute, sensitive speed control of all movements being obtained simply by regulating the pump delivery.

All control valves are conveniently grouped at a control panel at one operating position. Automatic valves lock the operating motions in the event of failure in the hydraulic system. The total weight of the 67-foot plant is about 20 tons, excluding the pile hammer, the heaviest single item being the machinery unit which weighs 4½ tons. It can be erected with the help of a 5-ton crane, fitted with a 50-foot jib. The base rings are transported in heavy sections which can be rapidly bolted together.

The new B.S.P. impulse pile driver represents a further technical advance in pile-driving technique; this machine has been designed to drive piles by a rapid succession of impulse forces. The prototype machine is powered by two 30-horsepower electric motors, which drive eccentric weights through chains and a linkage system designed to produce a rapid succession of downward impulses rather than a succession of blows, as in a conventional pile driver. These downward impulses are very heavy and may amount to 50 tons or even more in fully developed machines. A prototype machine, recently tested, drove piles of Frodingham Section No. 3 when operating at minimum power. Since the machine does not hammer the pile and is not driven by either steam or compressed air, it is claimed to be relatively noiseless in action.

The clamping device connecting the machine to the piles does not represent the final design. This will take the form of a friction grip operated by hydraulic power, which will connect the machine to the piles or release it almost instantaneously. The prototype is designed only for driving piles, but further research may reveal a method of adapting it to pile extraction.

Steam piling equipment is widely used, but the boilers and ancillary equipment are cumbersome and must be erected by skilled men (figure 2). The McKiernan-Clayton steam generator (figure 4) has been designed as a complete self-contained steam-producing unit which is easily transportable, requires no skilled supervision, operates automatically and combines high efficiency with reliability. This generator is ready for operation as soon as the water line has been connected; it is mounted on a rigid steel base and can be lifted and transported as one unit. Starting, operating, blow-down and stopping instructions are mounted on the control box so that the operator, even if he is completely unfamiliar with it, can work the unit. Valves are labelled.

Efficiency, flexibility, fast steaming and compactness are claimed as the outstanding features of this generator, which operates on the basic principle of forced recirculation of the water within the system. This principle is quite simple; the water is circulated at high velocity through a continuous coil and attains steam temperatures as it flows through the heating zone. It then passes into the accumulator, where steam and water are separated by centrifugal action. The steam is discharged for use, the water dropping to the bottom of the accumulator where it is picked up by the recirculating side of the pump and returned to the heating cycle with negligible loss of heat.

The generator responds instantly to fluctuating demands within its rated capacity, and will automatically maintain that pressure at which it is set to operate between 65 and 150 lb. per square inch. It cycles on and off in response to the load with the result that it consumes fuel only when steam is required. It will produce no more steam than is required by a piling hammer, so that although it