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COOPERATIVE RESEARCH

VIBRATORY PILE DRIVING
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VIBRATORY PILE DRIVING

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1. Barnes, B.E., " Three types of hammers drive miles of piles at fast clip", Construction Methods & Equipment December 1963, p 78.

To shoot a man to the moon, you first have to drive a lot of piles deep into the earth.

Blount Brothers Corp. found that out on their $8-million foundation job for the Cape Kennedy building in which the Saturn V lunar rockets will be assembled--it calls for 4,182 open-end pipe piles about 160 ft. long. Vibratory, diesel, and steam hammers drive the piles, which are 16-in. OD and have a 0.375-in. wall.

Pile sections are delivered to the job site in three lengths. Bottom of each pile is a 63-ft length. The second section is 45 ft. and the third, or top, section is 45 or 55 ft long, depending on depth to bedrock.

Originally, Blount drove a first pile section, welded the second to it, drove again, welded the third section on, and drove the complete pile to bedrock.

But after about 35% of piles had been driven, the contractor switched to a welding-bed operation that makes the first splice while sections one and two are horizontal in the yard. The two combined sections are driven until the hammer is 3 ft from ground level. Then a third section is welded and the pile is driven to bedrock.

Horizontal welding is handled in three on-site beds. Each bed has a rack made of six 45-ft pieces of pipe laid down, partially covered with sand, and levelled perfectly for precise fitting of the pipe joints to be welded. Welding crews then can work easily with six double sections of pipe on a bed at once. Welders make butt welds of 3/16 in. mild-carbon electrode, easily hand-rolling the piles across the bed frames as they make their five welding passes.

Each welding bed has its own crane and welding units. One bed's pipe handling is done by a 40-ton Link-Belt LS-108 crawler crane with 90 ft. of boom. Each of the other two beds has a 30-ton Northwest crawler crane, each with 80-ft. of boom.

There are 23 welding machines on the job--20 Hobart 250-amp units and three Lincoln 200-amp machines. Each welding bed uses four machines; the rest travel the job, for use in making upright splices.

For driving, Blount uses three French vibratory hammers for the first 118-ft of pile, then follows up with conventional hammers--two steam, four diesel--to drive the remaining 45 or 55 ft to bedrock.

On about half the holes, there is an 8-ft top layer of clay and vegetable matter that would plug the pile and slow the vibratory-hammering cycle by at least 20 min per pile. So Blount brings in an augering rig that drills an 8-ft hole every 3 to 5 min.

Piles for the Saturn assembly building are driven on 4-ft centers, clustered primarily in rectangular patterns and in straight lines. Pile clusters contain from 25 to 65 piles. Some 20% of the piles are placed singly to support grade beams. The rest are in clusters, to support the building's structural steel.

The crews drive about 10,000 ft of piling per 10-hr day. The vibratory hammers, supplied by L. B. Foster Co. drive between 65 and 70% of this footage. But Blount Brothers men point out that this doesn't really mean that a vibratory hammer can do five times the work of a conventional hammer in putting down a complete pile on this job. They note that the last 45 to 55 ft would be difficult or impossible for the vibratory hammer to complete. And the conventional hammers could drive the piles through the upper part of the installation twice as fast as they actually drive the final pile stage.

2. Esson, D.M. Ross, "Pile driving by vibration", <u>Civ Eng & Pub Works Rev</u> 58: n 679, pp 205-208, Feb 1963; n 680, pp 389-391, March 1963; n 681, p 487, April 1963.

The development of a new means of piling which is at once faster, more efficient and infinitely more quiet is described, with reference to American and Continental practice. This is effected by vibrating the pile either at its own natural frequency or that of the soil into which it is being driven. Quite remarkable results have been achieved so far, and the system will probably supersede conventional methods.

3. Grindrod, John, "Vibration-pressure method of soil preparation for concrete pile driving", <u>Indian Concrete J</u> 33: n 11, pp 389-390, November 1959. <u>J--Am Concrete Institute</u> 31: n 9, pp 893-894, March 1960.

Discusses a new vibration-pressure method of compaction known as Das Rutteldruckverfahren which had been developed by a German firm. This method has been found advantageous when used in connection with driving of concrete piles or anchor blocks.

The German compacting machine is introduced into the soil down to the desired depth and from this level upwards compacts a spherical volume of soil about 5-ft radius. By a pattern of insertions side by side it is thus possible uniformly to compact soil masses of any desired dimension and depth. The distance from one insertion to another being governed by the degree of load bearing capacity required and by the structure of the soil.

By this method the soil is not only exposed to the vertical and horizontal vibrations of the machine but the compacting process is enhanced by forcing water through the tubular shaft for emission through slots near the vibrator, which is operated electrically. Compaction takes place as the machine is gradually withdrawn from the depth to which it has been sunk, leaving a cylindrically shaped compact mass which is capable of taking much shorter concrete piles than would otherwise have been required. The article describes an application of this method for an artificial fertilizer depot in Holland. The pile length was reduced from about 42 ft to 16 ft thus permitting a considerable saving.

4. Gumenskii, B.M. and N. S. Komarov, "Soil drilling by vibration", Authorized Translation from the Russian: Published by the Ministry of Municipal Services of the RSFSR in Moscow in 1959. Consultants Bureau, 1961, 80pp.
<u>Nat Research Council--Highway Research Board Abstracts</u> 32: n 5, May 1962, p 12-13.

A very promising new type of geological exploration tool, vibrodrilling in soils, has been introduced in recent years into the field of engineering-geological investigations. As tests on the use of vibrodrilling have shown, the technique is suitable for engineering-geological investigations on construction areas and on railroad and highway beds, and in prospecting and exploring for construction material and other mineral deposits. Vibrodrilling may be especially effective when drilling holes for heat treatment of the soil, for the setting of sand piling, for horizontal and vertical drainage, and for treatment of ills in earthen railroad beds; that is, for those circumstances when a precise geologic section is not required.

Even in the early stages of the use of vibrodrilling, when the existing equipment was imperfect, the penetration rate was 4-5 times that of manual percussion-rotary drilling, at the same time lessening the labor of the operators and furnishing more complete results.

However, the technique of vibrodrilling has been, until now, inadequately treated in the technical literature, and this fact has made it difficult to expand the use and development of the method.

This book is a generalization of experiments by various organizations and of special studies made by the authors at the Leningrad Institute of Railroad Transport Engineers, partly in cooperation with the Leningrad Institute for the Planning of Transportation of the Ministry of Transportation Construction.

Since one of the principal problems in vibrodrilling in clay soils is the behavior of the soils during vibration, this book devotes considerable attention to thixotropic alterations (liquefaction and subsequent solidification of soil) as the chief factor aiding the easy penetration of the drilling instrument (or other object) even in dense clay soils.

In analyzing the results of investigations and tests on vibrodrilling the following points need explanation: (1) the relationship between composition of colloidally dispersed minerals in the clay soils and their capacity to undergo thixotropic change; (2) the nature of the processes originating during vibrodrilling in clay soils, since there are no data at the present time on this problem; (3) the conditions under which the capacity to soften and liquefy appears during vibration in clay soils; (4) the relation of the capacity to soften and liquefy in clay soils to the effect of direct electrical current and ultrasonic waves; (5) the dimensions of the zone of softening or liquefaction in clay soils during vibrodrilling; (6) the degree of precision in describing and measuring geologic sections from vibrodrilling data; (7) the possibility of ascertaining hydrogeological conditions during vibrodrilling; (8) the degree of disturbance to a number of soil properties during vibrodrilling. Other problems are also considered briefly in the book.

For some of these problems concrete solutions have been advanced, such as the instructions on methods of conducting vibrodrilling operations. In considering other problems, only the principal solution is discussed, particularly in regard to the question of employment of electroosmosis during vibrodrilling, for which only the most feasible application is commented upon. For a number of other questions, the authors have confined themselves merely to scientific statements of the problems, very important preliminary steps, inasmuch as the problems are urgent but are as yet completely uninvestigated. This group of problems includes, in particular, imperative studies on the effect of ultrasonic waves and of active substance of various compositions for lowering and even completely removing the capacity of soils to undergo thixotropic alteration, on the one hand, and for increasing the process to a maximum, on the other.

5. "Report on vibrated concrete," Highways and Bridges and Engineering Works 24: n 1155, p 4, September 1956.

The report on "The Vibration of Concrete" prepared by the Joint Committee of the Institution of Civil Engineers (Great George St., Westminster, London, S.W. 1) and the Institution of Structural Engineers (147 Victoria St., London, S.W. 1), has been published in the form of a fully illustrated booklet.

The Committee makes 11 points for a draft specification for vibrated concrete additional to the clauses of a normal specification, and calls for further research on seven points as follows:

1. It is essential that the vibrations of particles should be measured. This can be done by the method devised and advocated by Whiffin, Morris and Smith. This has been carried far in the Road Research Laboratory, especially in connection with surface vibrators. To the Committee's knowledge no such systematic research has been carried out in other types of vibration.
2. There is still doubt as to the best proportions of immersion vibrators, such as the ratio of length to diameter, etc.
3. The development of a simply applied test apparatus for determining the workability of the concrete in the mixer or as it leaves the mixer is required.
4. Design of mixes for vibrated concrete in relation to the tensile and crushing strengths, elastic modulus, bond, permeability, shrinkage and creep, especially for lean and gap-graded concretes.
5. The best type of mixer for dry concretes as used for vibrated work.
6. The wave-form and direction of vibration and the best frequencies and amplitudes with all types of vibrators.
7. The best methods of placing the concrete in various types of structure and the best positions of vibrators.

6. "Soil compaction and pile foundation construction by means of the Keller vibration driving method" Baumaschine u Bautechnik 4: n 12, p 411-416, 1957.

In the method developed by the Johann Keller G.m.b.H., the soil to be compacted is not only subjected to vibrations, but also has astream of water passed through it. The water, which is ejected from the vibrator tip and rises to the surface, holds the sand particles in the immediate vicinity of the vibrator in suspension and the vibrator sinks under its own weight to the required depth in the pappy soil, whereupon compaction begins in an upward direction. Where piles are required, they are introduced with the vibrator and the soil is compacted around them in the same way.

7. "Sonic pile-driver tests and performance", Military Engineer 54: n 362, pp 440-441, November-December 1962.

Pile driving has become such a large industry that any new or improved device or method for placing piles with increased efficiency can mean major savings in construction costs. Such developments as the differential steam, hydraulic, and sonic pile hammers have appeared very recently. The most revolutionary of all is the Bodine pile driver which is a process capable of placing piles by utilizing the tremendous power in sound waves. With this method the pile gives the appearance of dropping into a hole.

The limited data available tend to indicate that piles may be placed rapidly by the Bodine hammer in cohesionless and cohesive soils and in mixtures of sand and clay soils and will have carrying capacities much higher than piles of the same length place by conventional means. Its applicability to the pacement of light gage shells, mandrel-driven, has been demonstrated by the rapid driving of over 200 piles of the Cobi type on two separate projects.

The rapidity with which piles may be placed sonically is a basic result of the high degree of efficiency in energy transfer due to the pile being vibrated at its natural frequency. With the conventional hammer, a great deal of available power is dissipated in forms of heat and deformation and in overcoming inertia. Consequently, the energy available for driving at the bottom of the pile is greatly reduced.

Driving and load-test data are being accumulated in an attempt to establish an empirical relationship between allowable pile carrying capacity, horsepower input, and rate of piling penetration. Once this is compiled, general acceptance by engineers of vibratory means for placing friction piles should follow.

8. Stedling, Jerry A., "Sonic pile driving", North Carolina Engineer 20: n 1, October 1963, p 23-28.

Driving piles with soundwaves.

9. "Vibratory hammer from France drives piles fast", Construction Methods and Equipment 44:n 9, p 100, September 1962.

A new type of vibratory pile driver is helping install a sheetpile cofferdam in Providence, R.I. Made in France, the device is effective in non-cohesive soils. The hammer drives about four times as fast as a conventional double-acting steam hammer delivering 8, 750 ft-lb per blow at 145 strokes per min.

The job involves driving 75-ft sheets of Bethlehem SP-6a piling for a cellular cofferdam. The French pile hammer that drives them is about 8 ft high and weighs 7,000 lb. Within it are two 17-hp electric motors. Each motor through a roller chain drive, turns a series of shafts fitted with eccentric weights. These revolve rapidly and vibrate the sheet pile on which the hammer rests. The shafts and their weights are synchronized so that the only force imparted to the pile is a lengthwise one.

To transmit the vibrations efficiently, the bottom of the hammer is fitted with hydraulically operated jaws that grip the pile web tightly. This clamping action also eliminates deformation of the pile top during driving.

The hammer is controlled by a man on the ground. He operates jaws and vibrator motors by push buttons on a carry-around panel board hooked to the hammer's control box, which feeds electric current from a generator to the hammer. The new vibratory unit is almost noiseless in operation, imparts minimal shock waves into the soul surrounding the pile, and is an excellent pile extractor.