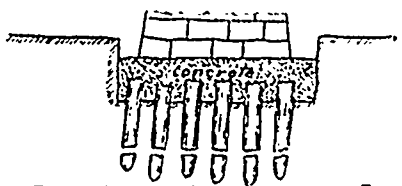
wrought iron screw piles are used extensively in ocean jetty, lighthouse, and pier construction, but for foundations to masonry structures on land the wooden pile is in



Foundation on piles and concrete. Fig 66

almost exclusive use ; of the various ways of driving piles by steam hammer, drop hammer, water jet, gunpowder explosions or insistent weight, the first three are the only ones worth considering.

The water jet is used economically where water is plentiful, ordinary pile driving inconvenient, and in sandy, quicksandy or silty soils (indeed it is often the only means of driving piles in bad quicksands), the water is carried in a pipe down the side of the pile and is projected in large quantities and considerable pressure just below the point of the pile ; this allows the pile, assisted by a dead weight or by light blows from a small hammer, to sink very rapidly, the water rising in a film around the surface of the pile and almost eliminating friction as long as the action continues, but after driving is finished the sand or earth settles around the pile and gives as high a bearing power as with hammer-driven piles.*

The Steam Hammer weighs from 4,000 to 5,000 lbs. and sits on the head of the pile, striking a blow with a piston loaded with about 3,000 lbs., the stroke is 2½ to 3 feet in length and about once per second. This keeps the soil and pile in a continual vibration and effects more than the occasional, though more severe blow of a drop hammer. Although a steam hammer is unable to drive in very hard ground economically, and is not economical where only a few piles are to be driven in a place, as the cost of transportation of hammer, boiler, steam-pipes, etc. is too great, yet wherever a great many piles are to be driven in one locality, as on docks, large foundations, etc., or where the outfit can be economically transported from place to place, it can drive piles much more cheaply and quickly than a drop hammer.

The Drop Hammer is raised either by hand, horse, or steam power, and usually a trip is arranged to free the hammer automatically at the top, the line being brought down again by hand, which takes time. In order to avoid this, sometimes, in driving by steam, the line is permanently attached, and a friction drum is utilized to let it drop without tripping, thereby dragging the line with it and lessening the force of the blow, but economizing time. The chief danger in this method lies in its abuse by dishonest contractors, where the pile-driving is specified for certain maximum penetration at the last blow, in which case, a slight friction on the drum will materially lessen the effect of the blow. The weight of drop hammers varies from 1,200 to 2,000 lbs., and the drop from 15 to 30 feet depending on the hardness of driving and pile head, and length of leads. The drop and steam hammer are in general use, and the load which a pile can safely carry may be approximately estimated by various empyrical formulæ, when the drop, weight of hammer, and penetration at the last blow (with an unbroomed head to the pile) are known, such formulæ are usually on the safe side, because although at least one instance has been given of a pile refusing to drive at all, and yet after a day's rest going five or six inches, yet the usual experience is that piles which will penetrate several inches at a blow, after long continued driving, will penetrate less, or almost refuse to drive after a rest of a day or two allowing the material to settle around the pile.

The three formulæ looked upon most favorably in America are:—

(*a*) Weisbach's or Sanders—

$$\text{Safe load} = L = f \times \frac{12\,WH}{S} \quad (f = \tfrac{1}{3} \text{ to } \tfrac{1}{8}).$$

(*b*) Trautwine's—

$$\text{Safe load} = L = f \times \frac{46\,W\sqrt[3]{H}}{S+1} \quad (f = \tfrac{1}{3} \text{ to } \tfrac{1}{12}).$$

(*c*) Wellington's—

$$\text{Safe load} = L = \frac{2\,W\,H}{S+1} \text{ (drop hammer).}$$

$$\text{Safe load} = L = \frac{2\,W\,H}{S+\frac{1}{10}} \text{ (steam hammer).}$$

(L = safe load in lbs. ; W = weight of hammer in lbs. ; H = drop of hammer in feet ; f = factor of safety; S = penetration, per blow, in inches, for average of last four or five blows.)

Where penetrations are as much as two inches or over there is not much to choose between all these formulæ; but for small penetrations the 1st one is evidently inapplicable, giving abnormally high results; on the other hand, the third formula is conservative under all conditions, simple in use, and admits of a modification for steam hammer driving, in which *stiction** is not an element to be considered. It is also applicable down to zero penetrations for ordinary weight of hammer, drop and length of pile, as $L = 2\,WH$ is about what a pillar 12 or 15 inches in diameter and, say, 20 feet long will safely stand (taking W = 2,000, H = 25).

These formulæ neglect many small losses of energy in driving, and are, therefore, only empyrical; but the results accord fairly well with the few facts known regarding the safe loads on piles. Evidently in ordinary soils, the skin friction is the important element in their sustaining power, as the load carried on the point of even a blunt ended pile would not be very great unless on solid rock.

Of the ordinary losses of energy in pile-driving, the only important one (neglecting the friction of the leads, the compressing of the pile, the bouncing of the hammer, which latter can be remedied by lessening the drop, or getting a heavier hammer), is the brooming of the head and point under hard driving. To prevent the former, a hea· on band about three inches by one inch should be fitted around the head, and when brooming does occur, it should be sawed off at once. While in hard or bouldery ground the point should be shod with straps of iron and made rather blunt—in fact some drive with piles almost without a point, claiming that brooming is thus prevented—in quicksand, a pile turned butt downward will often be the only means of keeping it down during driving, and in all cases where piles are subject to severe vibration they will take a much less load than where it is a quiescent one. This is not included in the formulæ and must be provided for in the design.

For permanent piling in fresh water districts such woods as cedar, oak, yellow pine, rock elm, spruce and tamarac are in common use, being given somewhat in order of merit for durability, while any good wood may be used for temporary work. The cost for ordinary lengths will vary from five cents to eight cents per foot in favorable localities, to twelve cents or fifteen cents for oak piles at a greater distance, and even twenty-five cents or

*See *Engineering News*, Vol. 31, 1894, page 316, for jet pile driver.

* Stiction is that excess of frictional resistance offered, when a body is started from rest, over the continuous frictional resistance offered to a body while in motion, under the same conditions of surrounding material. C. B. S.