FOUNDATION BOLTS

It is often difficult to locate bolts in concrete with sufficient exactness for setting a machine. To obviate this difficulty, the head of the bolt should be provided with a large washer* to give a good bearing surface, the bolt placed in its approximate position, with washer down, and an iron pipe or a light wooden box placed around the bolt resting upon the washer. When the machine is set, to prevent the bolt from rusting, the iron tube or box should be filled with mortar. In any case the tube or box should be filled with sand before the machine is poured up with sulphur or cement grout, in order to keep these materials from running down the bolt holes.

CONCRETE PILES

Concrete piles may be employed in place of wood where the loading is excessive, and where the durability of timber piles is questioned either because of probable worm action or the rotting of the timber. If the bearing is frictional and the piles are driven through ground which is continually wet, there is usually no advantage in concrete over timber piles unless in certain instances where the low level of the ground water or the tide water is so far beneath the structure that the concrete piles permit the commencement of the foundation at a considerably higher level and thus save excavation and material.

Concrete piles are formed (1) in place, or (2) are molded above ground and driven with a pile driver.

Various methods have been suggested for forming the hole into which the concrete is to be placed. One of the patented processes consists in driving a double shell of metal into the ground, removing the inner one, and leaving the outer to form a mold for the concrete. The two shells and pile driver are shown in Fig. 207, page 652. The inner shell or pile core, which is of heavy sheet steel and constructed so that it can be made to collapse for removal from the ground, is placed within the other thinner shell, and driven like an ordinary pile. The core is then collapsed and withdrawn, leaving the outer shell, which is closed at the bottom, to be filled with concrete. By providing considerable taper, additional support is obtained from the soil.

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* The washers, which are used for transmitting the pressure of large bolts to the concrete or other foundations, should be carefully designed with heavy ribs so as to transmit a uniform pressure per square inch of area. Neither wrought nor cast iron plates should be used for washers under large bolts.

Another system, illustrated in Fig. 206, consists in driving a single shell with either a concrete or a steel point, then slowly withdrawing it, and filling the space which it occupied with concrete whose surface is kept far enough above the lower end of the tube to maintain the head necessary to resist the pressure of the ground.

In still another method, which is especially adapted for underpinning, the tube is washed down with a water jet to firm strata, and the bottom of the excavation is enlarged by an expanding arrangement to form a base, as shown in Fig. 208.

Piles made in situ may be reinforced if desired.

Cast Piles. Reinforced piles which are formed above ground are designed like columns with vertical reinforcement connected at intervals with horizontal wire rods.

The pile* used in a foundation for the Boston Woven Hose & Rubber Company, Cambridge, Mass., is illustrated in Fig. 209. These piles averaged about 30 feet long. The hammer weighed 4700 pounds and the blows were cushioned by a head consisting of a plate iron collar 16 inches square on the inside and 3 feet in height, which incased an oak block 16 by 16 by 18 inches, to the bottom of which six thicknesses of rope and four layers of rubber belting were nailed. The piles were

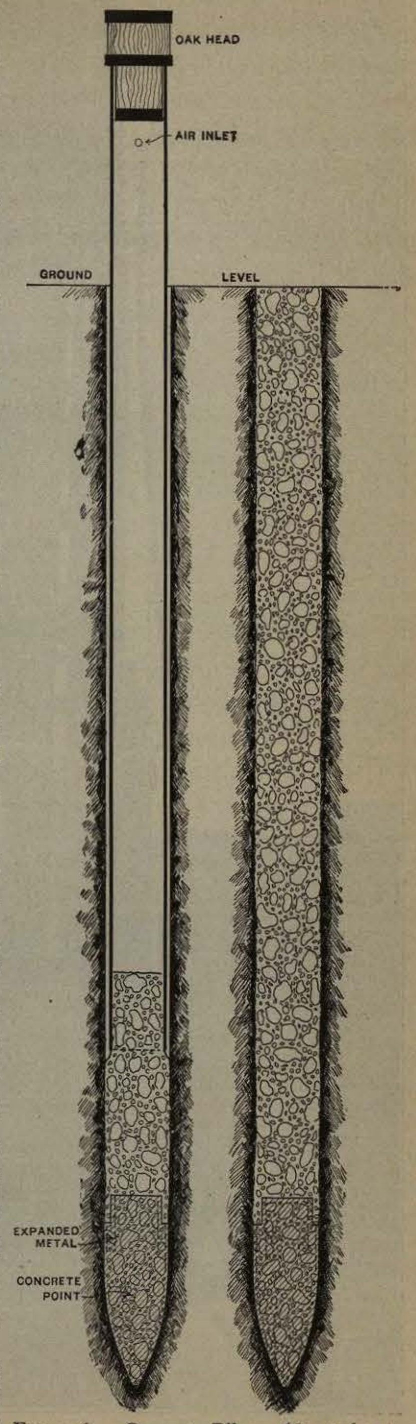

FIG. 206. — Concrete Piles. (*See p.*651.)

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* For full description of piles and driving see "Cast Reinforced Concrete Piles," by Sanford E. Thompson and Benjamin Fox, Journal Association of Engineering Societies, Vol. XLII, 1909.

FIG. 207. — Cores for Concrete Piles. (*See p.*650.)

driven at the age of thirty to forty days. The usual drop was 3 feet, but in some cases this was increased to 10 feet without injuring the pile.

The designs drawn up in 1903 for the Pennsylvania Railroad Tunnel[*] under the Hudson River call for a shell of cast iron surrounded by concrete and supported at intervals by steel screw piles filled with concrete.

Sheet Piling. Poling boards of concrete were employed by Mr. Howard A. Carson, Chief Engineer in the construction of the approaches to the East Boston Tunnel. These are described[†] as follows:

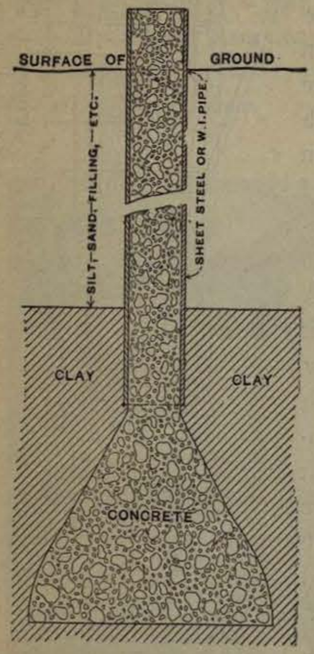

FIG. 208. — Concrete Pile with Enlarged Footing. (*See p.* 651.)

> The excavation was through gravel and clay, and through sand containing some water. Trenches 16 feet long and 16 feet apart were dug to about the level of the bottom of the building foundation. Below the foundation one-half of each trench, or 8 feet in length, was carried down to grade. The bank below the foundation was held in place by means of concrete slabs used as sheet piling, as illustrated in Fig. 210. These slabs were from 6 to 8 feet long, 6 inches wide, and 2 inches thick, and each was reinforced with six square steel rods running the entire length of the slab and shown in Fig. 211. If wooden sheeting had been used, it would have been necessary either to have concreted directly against it and left it in place, or to have pulled the planks as the concrete was filled in. If the first method had been used, the planks would in time have become rotten, leaving a vacant space. If the planks had been pulled, there would have been danger that some of the earth under the building would run and a settlement of the building follow. In order to guard against any slight voids which might have been left in driving, grout was poured in behind the sheeting. This sheeting served not only to hold the bank in place, but was used, in place of a back wall, to waterproof against. The sheeting was not disturbed, and the wall of the Tunnel was built directly against it.

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[*] *Engineering News*, Oct. 15, 1904, p. 331.

[†] Ninth Annual Report, Boston Transit Commission, p. 41.

BRIDGE PIERS

Concrete is employed for bridge piers either as filling for ashlar or cut masonry or for the entire pier. In the latter case, in which the face is also of concrete, the chief question is as to its ability to withstand the wear of the water, the ice, and floating debris. Mr. Martin Murphy* stated as early as 1893 that concrete was generally adopted in Nova Scotia, and with successful results, for abutments and piers "in the most exposed positions, in the midst of strong currents, without any external protection, where exposed to heavy ice floes, to blows from timber rafts, and, in many instances, to undermining by scour." In Nova Scotia it is the common practise to construct the body of the pier of rubble concrete with a 6 to 9-inch facing of richer concrete. In answer to inquiries, Mr. Murphy wrote the authors in 1904: "The concrete piers erected in this Province for the last eighteen or twenty years have withstood the action of the weather, and fulfilled all that was claimed for them in my paper, read before the International Congress in 1893. The erection of such piers and abutments is now in almost universal application in Canada."

In the Kansas City flood of 1903, the piers of solid concrete, although located where they were struck by all the heavy debris which totally destroyed many of the stone masonry structures of the same size, remained practically uninjured.

In 1900 a Committee of the Association of Railway Superintendents of Bridges and Buildings† made the following inquiry: "For what classes of structures do you use Portland cement concrete?" Out of thirty-three replies received, seventeen were in favor of employing this material for both the foundation and neat work of bridges, piers, and abutments.

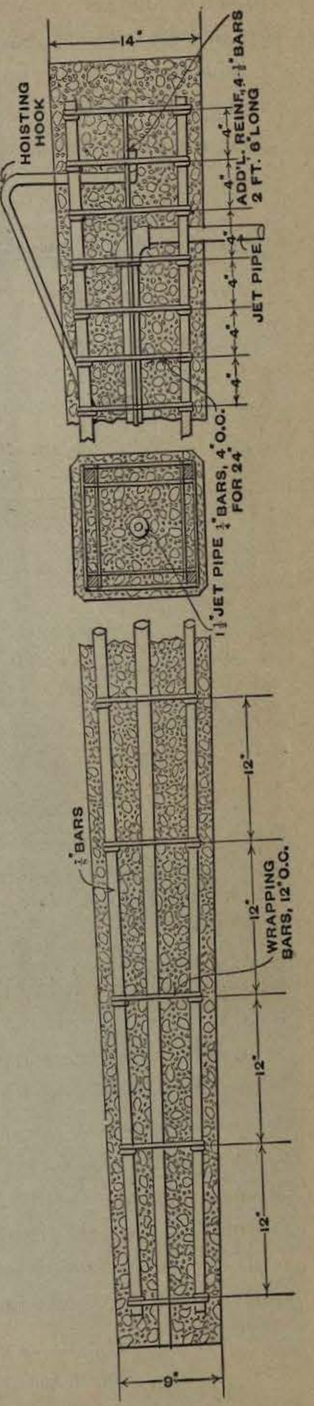

FIG. 209.—Piles used at Cambridge, Mass. (*See p.* 651.)

Plastering of concrete piers and abutments should be prohibited. If a mortar surface is required, an excellent facing, to be placed next to the form as the concrete is laid, is a mixture of one part cement to 2½ parts hard broken stone screenings ½ inch in size and under. Ordinarily, however, no surface finish is required unless superficial treatment is given for the sake of appearance. (See p. 288.)

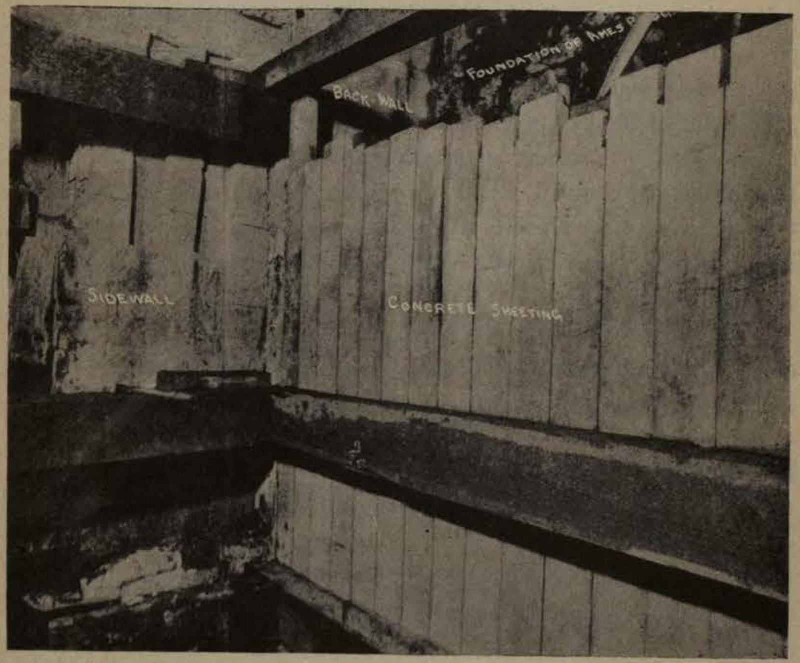

FIG. 210.—Concrete Sheet Piling in Approaches to East Boston Tunnel. (*See p.* 653.)

Pier Design. Most railroads are substituting concrete for ashlar masonry in bridge piers.

The standard pier of the N. Y. Central R. R., adapted to any height up to 40 feet, is shown in Fig. 212, page 657.* The width, which depends upon the length of span, is as follows:

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*Bridge Substructure and Foundations in Nova Scotia, Transactions American Society of Civil Engineers, Vol. XXIX, p. 620.

*Arranged from original drawing, for which the authors are indebted to Mr. Wilgus.

Spans up to 40 feet width, A, = 4 ft. 0 in.
Spans 40 to 60 feet width, A, = 4 ft. 6 in.
Spans 60 to 80 feet width, A, = 5 ft. 0 in.
Spans 80 to 100 feet width, A, = 5 ft. 6 in.
Spans 100 to 125 feet width, A, = 6 ft. 0 in.
Spans 125 to 150 feet width, A, = 6 ft. 6 in.
Spans 150 to 200 feet width, A, = 7 ft. 0 in.
Spans 200 to 250 feet width, A, = 7 ft. 6 in.
For skew crossings, increase width, A, if necessary.

Foundation is varied to suit local conditions. Concrete 1:3:6 is employed for it unless stone masonry is cheaper. The starkweather is carried 2 feet above high water, and its cap is of 1:1:2 concrete. The coping of the pier is reinforced with galvanized wire netting or wire cloth, a somewhat unusual requirement.

The Illinois Central R. R., in their 1904 design, reinforce the surface of piers with vertical and horizontal steel rods, and imbed a single I-beam in the pointed nose at each end of the pier.*

The Chicago, Milwaukee & St. Paul Railway Company takes the extra precaution to strengthen the noses or starlings of its concrete piers only at points where there is considerable ice and driftwood.† They build a 7-inch street car rail into the nose of the pier, with the head projecting slightly from the concrete. Other roads also show no reinforcement in their standard design.

It would appear that reinforcement is probably unnecessary except in situations where the piers are subjected to unusual impact.

All of the roads named above have piers in streams which subject them to considerable wear from ice and drift, and the concrete has proved satisfactory.

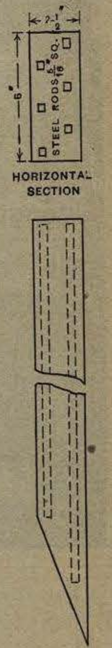

FIG. 211,—Sheet Piling. (*See p.* 653,)

FOUNDATIONS UNDER WATER

The best and most durable concrete foundations, especially in work in sea water, are laid within cofferdams from which the water has been pumped, or in pneumatic caissons. However, because of the difficulty and expense of these methods, they cannot usually be followed. If the bottom is prepared by dredging, and, if necessary, driving piles, good practise permits the use of a single line of sheeting, suitably supported with rangers, to prevent the wash of the water and keep the concrete from spreading.* Permanent metal cylinders are sometimes sunk in place of the sheeting.

Methods of laying concrete under water are described in Chapter XV, page 301, and the effect of sea water upon concrete is discussed by Mr. R. Feret in Chapter XVI.

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*From drawing kindly furnished by H. W. Parkhurst, Engineer.

†Authority of C. F. Loweth, Engineer.

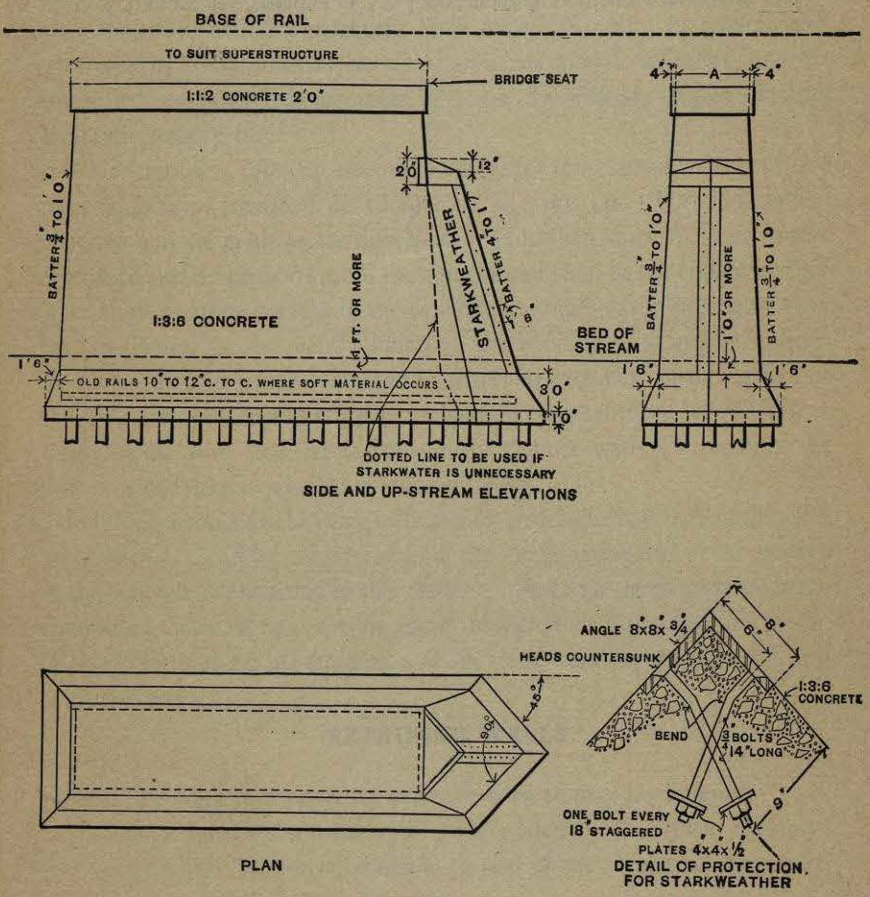

FIG. 212.— Standard Concrete Bridge Pier, N. Y. C. & H. R. R. R., W. J. Wilgus, Chief Engineer. (*See p.*655,)

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*See Foundations for New Cambridge Bridge, Boston, by Sanford E. Thompson, *Engineering News*, Oct. 17, 1901, p. 283.

For under-water work, a larger factor of safety should be employed than for work above ground, the concrete should be slightly richer in carefully selected cement, and the aggregate so proportioned as to give a dense and impervious mixture.

Concrete for the foundations of walls and piers for high office buildings is usually laid in oblong or circular caissons of steel or wood,* after excavating under air pressure. Steel pipes are sometimes sunk with the aid of the water jet, and afterwards filled with concrete.†

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*Engineering News, Sept. 26, 1901, p. 222.

†Jules Breuchaud, Transactions American Society of Civil Engineers, Vol. XXXVII, p. 31.

CHAPTER XXVI

DAMS AND RETAINING WALLS

For walls to resist the pressure of earth or water, concrete frequently possesses marked advantages over other classes of masonry. With proper management, in most localities its cost may be brought below that of rubble masonry. Its adaptability for thin walls and for certain classes of face work often make it a suitable substitute in complicated designs for first-class masonry, with a consequent large saving in cost. In combination with steel its possibilities for special designs are almost unlimited, and the future will see marvelous advances in its use for ordinary engineering and hydraulic construction.

Water-tightness, often an essential element for this class of structures, has received general treatment in Chapter XIX, page 338. Portland cement concrete may be made water-tight more readily than stone masonry laid in mortar of similar proportions to the cement and sand in the concrete, since large voids or stone pockets in the concrete are more easily prevented than the "rat-holes" so frequently found in the bedding of stones in mortar. Moreover, skill in laying combined with special treatment of the surface or the addition of certain ingredients permits construction in concrete—strengthened with steel reinforcement—of thinner walls for resisting the flow of water than is possible in stone masonry.

Reinforced concrete retaining walls cannot be designed by "rule of thumb," and therefore a careful consideration of the forces acting and of the stresses in the concrete is presented in this chapter. Since the earth pressure is the controlling factor, it has been necessary to introduce a practical discussion of this before taking up the details of the design and examples of the two principal types

RETAINING WALLS

Retaining walls to support the pressure of earth may be designed:

(1) of gravity section with plain concrete or stone masonry;
(2) of thin reinforced concrete section of the inverted T type with spreading base or footing;
(3) of thin section, reinforced and supported by buttresses or counterforts.

Another plan sometimes adapted to cellar wall construction (see p. 619) consists in embedding the base and supporting the top of the wall with tim-