

PILE FOUNDATIONS FOR TUNNEL TUBES.

In a recent editorial on "Tunnel Tubes in Soft Material," we pointed out the necessity of providing adequate foundations for the railway tunnels which are now being built in New York city under the North and East rivers. The question is not by any means a recent one with engineers, although it is only of late that the public has begun to appreciate its importance, particularly with regard to the Rapid Transit tubes below the East River. In this connection, we are glad to note that the condition of these tubes is to be made the subject of special investigation, both with regard to their strength to resist distortion and the necessity of providing for their vertical stability.

Among others who have carefully studied the problem of tunneling through the soft material of our river bottoms is Mr. J. W. Reno, of this city, whose project for double-deck subway construction has more than once formed the subject of illustration in this journal. Mr. Reno is of the opinion that some form of anchorage and support is necessary for any tubes that may be built through the mud and silt of these rivers; and he believes that, since it is desirable to avoid the heavy vertical reactions and horizontal torque, which are inseparable from the driving of iron screw-piles of large diameter, as proposed, better results would be secured by driving ordinary 12-inch piling in the manner described below.

The screw-piles proposed for the Pennsylvania tunnel tubes below the Hudson River are 5 feet in diameter at the screw and 27 inches at the shaft, and they are to be spaced 15 feet apart from center to center along the center line of the tunnel. It is proposed to put them down by a machine operated by hydraulic pressure which, at the same time that it rotates the pile, also bears down upon it with enormous pressure. The vertical hydraulic pressure upon the head of the pile must have its corresponding reaction against the roof of the tunnel. Moreover, the torsional reaction in a horizontal plane, necessary to rotate the pile in screwing it down, will tend to force the tunnel out of line laterally, just as the vertical reaction would tend to lift the tunnel. This will be the more appreciated, when it is remembered that before the tunnel has been lined with two feet of concrete it has a theoretical tendency to rise because of its buoyancy; for its weight is only about 15,000 pounds per running foot, whereas the semi-fluid material it displaces weighs 43,000 pounds per running foot, which gives a buoyancy in the tunnel itself of 14 tons per foot.

In the plan herewith illustrated, it is proposed to use 12-inch wooden piles, three or four abreast, at every 5 feet of the tunnel's length, instead of using a large-diameter, cast-iron pile at every 15 feet. The pressure required to force down a standard wooden pile would probably not exceed 20 tons per pile, as compared with a necessary pressure of 100 tons for the cast-iron screw pile—this last being the pressure determined as necessary in the case of test piles, which were sunk by the company's engineers.

For the driving of the wooden piles, Mr. Reno has designed the compact and effective apparatus shown in the accompanying engraving. The pile driver consists of a steel cylinder, large enough to contain a 12-inch pile. The cylinder is provided with trunnions and a hand wheel, by which it can be moved from the vertical into the horizontal position, as shown in the drawing. When in this position the first 20-foot section of the pile is inserted, and the cylinder is then rotated back to its normal vertical position. A pressure of 375 pounds to the square inch, capable of producing 25 tons total pressure on the head of the pile, is then available on a short piston above the pile, within the cylinder, this pressure being secured by an electrically-driven hydraulic pump. When the head of the pile has been sunk to the floor of the tunnel, the second section is spliced on and driven in like manner, on the top of the first pile.

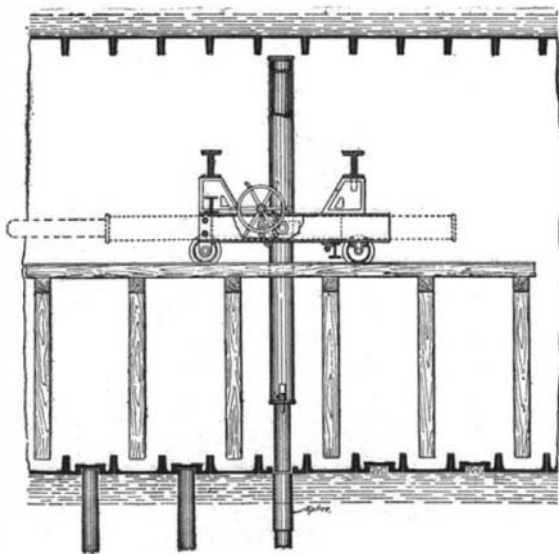
The carriage containing the pile driver is so constructed that the hydraulic cylinder may be moved laterally and three piles driven, side by side, in each bent. It will not be a difficult matter to cut the circular holes for the piles in the thin cast-iron shell forming the floor of the tunnel; and after the piles have been driven, the holes would be securely plugged by the pile and by the concrete capping, 2 feet thick, with which the tunnel is to be lined. In order to

locate the pile driver in the most convenient position, an elevated timber platform is provided along the middle line and on either side of the tunnel, to which are bolted a pair of heavy beams, which serve as tracks for the pile driver carriage. The importance of designing a machine which will rapidly handle a heavy stick of timber, such as a pile, in the limited space found in the interior of a tunnel, will be understood when it is stated that, in this plan, 7,200 piles 40 feet long would be required in the foundation of the two Hudson River tunnels.

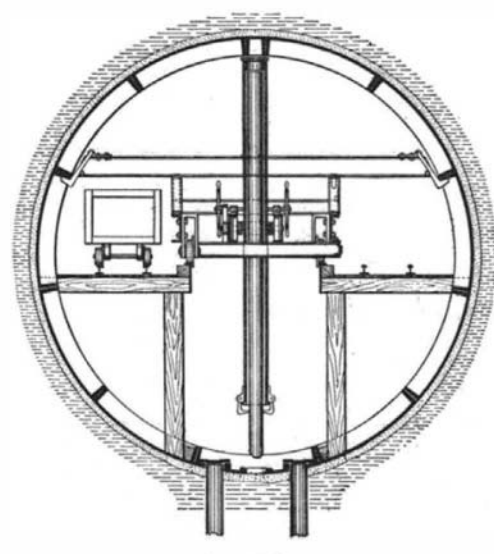
An important feature of the side platforms is the space which they provide for a pair of narrow-gage railway tracks, which serve the material cars in such a way, that the pile driver will not interfere with the passing of cars loaded with concreting or other material. By means of this arrangement, a pile foundation can be constructed simultaneously with the lining of the tunnel with concrete, with the result that there will be a considerable economy of time.

It would, of course, be undesirable that the vertical reaction of the downward pressure of the pile should be concentrated at one point of the tunnel roof; and, in order to distribute this pressure, two heavy I-beams are provided as part of the pile-driving outfit, which extend across the tunnel, and, by engaging the flanges at the points indicated, distribute the pressure over a large area of the roof. One of these beams is pivoted to the carriage, and can be moved out of the way, when the pile cylinder is rotated into a horizontal position.

By the method here described it is practicable to put down nine, or even as many as eighteen, piles, should it be so desired, in lieu of one large screw pile. Mr. J. A. Bense, Chief Engineer of Docks, has made some valuable tests upon the supporting power of wooden piles, driven in 40 feet of Hudson River silt, which



REACTION TRUSS FRAME, RENO HYDRAULIC PILE DRIVER.



Piles 40' long.

show that the piles, as here proposed for the Hudson River tunnel, will support a maximum load of 40 tons each. The Pennsylvania Railway Company will haul its trains through the tunnel with an electric engine weighing 105 tons, this weight being concentrated upon a wheel base of approximately 24 feet. For this distance the proposed plan of using three-pile bents would provide twelve piles, and if we assume the maximum supporting power at 40 tons per pile, as stated by Mr. Bense, there would be a total maximum support of 480 tons under the electric locomotive. It is, of course, obvious that piles could be driven under every segment of the tunnel lining, instead of under alternate segments, in which case the foundation would have a supporting power of nearly 1,000 tons for a length of 24 feet of tunnel. Finally, it should be noted that the strains upon the tunnel structure incidental to driving the piles is enormously reduced, for it is a fact that a pile can be forced down into the silt by a pressure of 15 to 20 tons, which, after it has stood for a few days, will remain firm under a pressure of from two to three times as great.

The Velocity of the Invisible Rays of Light.

The Boyden appropriation of \$1,000, offered nearly forty years ago by Urian A. Boyden, an eminent mechanical engineer of his day, has at last been awarded by the Franklin Institute to Dr. Paul R. Heyl, of the Central High School of Philadelphia, for determining by experiment whether all rays of light or other physical rays are or are not transmitted with the same velocity. The problem which Dr. Heyl has solved is not to-day a scientific problem of the first importance, and has not been for twenty-two years. That all rays of light are transmitted with the same velocity has been held on the basis of indirect and circumstantial evidence. Dr. Heyl has now supplied that direct evi-

dence of experiment which every theory ultimately demands. Dr. Heyl's essay is referred to a special committee consisting of Hugo Bilgram, Prof. Arthur W. Goodspeed, of the Department of Physics of the University of Pennsylvania, and Dr. George Flowers Stradling, of the Northeast Manual Training School of Philadelphia. The committee reported unanimously in favor of the essayist who had written under the pseudonym "Algol," the real person being only discovered after the award had been made. The manner in which Dr. Heyl has solved the problem cannot be more briefly and clearly expressed than in the following abstract of the committee's report:

Dr. Heyl succeeded in demonstrating, by experiment, that those of the ultra-violet rays of light for which glass is transparent have the same velocity as the light rays proper. He reasoned that if the velocity of these rays were different they would not arrive from a distant source, at the same time. For his test he selected Algol, a well-known variable star in the constellation Perseus, as the source of light. By means of a diffraction grating he eliminated all but the ultra-violet rays of a known frequency, and by focusing them on a sensitive plate obtained photographs of the star.

For the purpose of identifying the rays so recorded with the visible rays, regarding the time of their emission, he selected for the time of his tests the time during which the light of this star shows the peculiar phenomenon of fading and recovering. The period of this variation is known to be about six hours. During this period he took a number of photographs, one-half hour apart, each exposure being twenty minutes, the remaining ten minutes being employed for making the necessary preparations for the next exposure. He thus obtained a number of exposures of the star on the same sensitive plate, but shifted in position.

After developing the plate the successive images plainly showed a fading and recovering, although the exact location of the minimum brightness could not be absolutely determined, the approximate coincidence of the time of the minimum brightness of the visible and the photographed rays was obvious. These tests were repeated a number of times to eliminate the possibility of error and also to take in a certain range of the ultra-violet rays, and since favorable opportunity for making these tests is not frequent, the investigation extended over a period of two years.

The applicant then reasoned as follows: Assuming that the photographic minimum did not exactly coincide with the observed visual minimum, their difference did certainly not

exceed an hour, and since the distance of Algol is no less than forty light years the difference of the velocities of the ultra-violet and the visible rays could not exceed one part in 250,000. This close approximation established equality to all intents and purposes.

Cody Kites for the British Army.

Capt. Cody, whose man-lifting kites have been acquired by the British government, and whose services have been retained by the army balloon department, is at present engaged in experiments with a kite similar in design to those already in operation, but which is propelled by a gasoline motor. For the purposes of his investigations the large balloon shed has been placed at his disposal. During the recent visit of Prince Fushimi and King Edward to Aldershot a series of maneuvers and demonstrations were carried out with the apparatus under cover, which proved eminently successful. On this occasion the apparatus was held in check by slipping tackle to a rope running at 30 deg. from the ground from one end of the building to the other. When the motor was set in operation the kite traveled from end to end of the building steadily and evenly. So far it has been possible to carry out successful flights for a distance of 1,200 feet, the limit of the experimental range of operations, with two trail ropes and loaded with two 56-pound weights, which approximately coincide with the weight of the average man. During the present summer a number of larger flights over a greater range in the open air are to be carried out.

The foreign trade of the United States for the eleven months ended May 31 for the first time passed the \$3,000,000,000 mark in such a period and exceeded by \$320,351,760 the total for the corresponding months of the prior fiscal year.