added to this $3.60 per hour, or about 47 cents per yard; lights added 56 cents more; and these, with other contingencies, nearly equaled the cost of labor. The great cost was due to the excessive hardness of the material over much of the surface, the caisson finally resting over nearly its whole extent on a mass of boulders or hard pan.

"The concrete in the caisson cost about $15.50 per cubic yard for every expense. The caisson and filling together aggregated 16,898 cubic yards, and the approximate cost per yard for every expense was $20.71. This was less than the cost of masonry laid in the open air.

"The labor of making these estimates is very great; and it has not been done for the New York tower.

SETTLEMENT OF MASONRY.

"Bringing the account of the work up to the latest date,* it is sufficient to say, in closing, that the settlement of the Brooklyn tower, at the time of completing the masonry (measured from marks at all salient angles, which were made immediately after the work reached high water), averaged 0.101 ft., the extremes being 0.08 and 0.102 ft. The average for the New York tower was one and one-eighth inches, with a still closer correspondence, but the figures are not at hand.

"The settlement of the New York anchorage from the time of reaching 22 ft. above tide, when the levels of all salient angles were referred to a permanent bench mark, was three-quarters of an inch across the front, and one and three-quarter inches across the rear. The difference is, no doubt, due to the greater proportional weight at the rear. The figures for the Brooklyn anchorage are about the same, but are not at hand."

(TO BE CONTINUED.)

NEW CAISSON-COFFER-DAM FOR LOW FOUNDATIONS.

[Translated for Engineering News from Annales des Ponts, etc.]

The use of compressed air for laying the foundations of bridges has been greatly generalized of late years. Formerly it was only employed where the depth of the foundation had at least nine meters, afterwards it was used for depths of six, five, four and even 3.40 m.

The system possesses, in fact, the great advantage of allowing work to be carried on in all seasons; the cost too has been considerably reduced by competition, and there will be a further reduction, until it is about the same as for work in the open air.

Unfortunately, however, the use of compressed air for foundations at small depth presents some serious drawbacks. It is difficult to superintend the work when the work-chamber is filled with beton, and to put the caissons in place, because the work-chamber itself takes up the masonry of the foundation. There should be a sufficient depth of water so that the caisson and masonry executed during the sinking should be below the level of low-water mark. The caisson is always at least two meters in height and the masonry one meter, which gives at least three meters as the height of water which ought to exist between the level of the low-water mark and the bottom of the fitting in, if we make use of the usual system of foundations. Let us also remark that the caisson is lost, that the irons remain in the mason work, and that the expense under this head has a great influence on the cost in the case of foundations at low depths, representing only a small cubic extent of masonry. It may be said that the advantages of compressed air vary as the depth, while the objection and the cost vary in inverse ratio to this depth. There must be, therefore, a limit beyond which there is an advantage in using compressed air, and below which the open air system should be preferred. This limit appears to be between four and five meters.

For greater depths than five meters it is more advantageous to use compressed air, and for those below four meters to build in the open air. There are cases, however, in which this general rule cannot be followed, as, for instance, when bridges have to be built in one season over rivers subject to freshets which would disturb the foundations if built in the open air. It is preferable, in this case, to make a sacrifice and use compressed air. M. Liebaux had to build several bridges over the Dordogne in such conditions. He made use of a caisson-coffer-dam, which was both durable and movable, and the results obtained lead him to believe that the system is a solution of the question of employing compressed air for foundations at low depths.

This mixed system combines in fact all the advantages of compressed air, without any of the objections which are urged against it. All the difficult part of the work is done by compressed air—the taking away the silt and the fitting in. The mason work is then built up in the open air, and finally, when the pile is out of the water, the whole caisson is taken out without leaving a single piece of iron in the masonry.

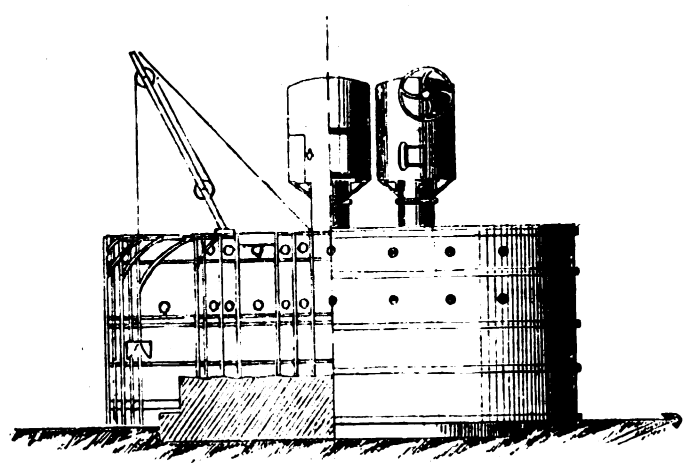

FIG. 1.—HALF LONGITUDINAL SECTION AND ELEVATION.

The putting in place is easy, and there is no difficulty in superintending the work. There is no minimum limit with this caisson, which offers a superior method of employing compressed air, and secures a rapidity and certainty of work which are offered by no other.

The apparatus, invented in 1879 by M. Montagnier, consists of a bell, five meters in height, in which the air is compressed, and under which the work of removing silt, the fitting in and the construction of the pile (Fig. 1 and 2) is carried on.

The caisson has the shape of the pile to be built, but it is larger in every respect, and this facilitates the putting in place. It is composed of vertical pieces of sheet iron of two meters in width, consolidated by horizontal T-irons, and small vertical beams. The pieces are banded together by T-irons and bolts. Strips of india rubber of 10 millimeters insure the absolute airtightness of each joint. The caisson is covered with a roof which is made very resisting by a series of beams of about 0.60 m. in height. The roof is joined with the caisson in the same way as the segments are with each other, and is supported inside by a series of braces, which are joined to the small vertical beams of the caisson. Interior frames made of T-irons complete and insure the rigidity of the whole apparatus. Finally three sluices, of which two are circular, and the third elliptic, give access to the caisson.

A scaffolding supported by two boats joined together are used for putting the caisson in place, the caisson being raised in the middle of the scaffolding by screw jacks of a power of 10,000 kilos. Knowing the weight of the caisson, of the scaffolding, and of the accessories, and the surface of the boats, we can determine beforehand what will be the sinkage of the latter. In order to resist the sub-pressure of the compressed air, the caisson is heavily ballasted with pig-iron placed on the roof between the beams, and the load is increased in case of a freshet. The caisson which was used in building the piles for the bridge at Garrett was thus loaded with a weight of 130 tons, and could have borne a much heavier load.

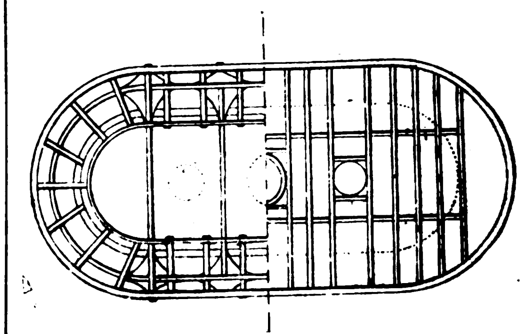

FIG. 2.—HALF HORIZONTAL PLAN AND SECTION.

The manner of operating is as follows: The caisson being put in place and ballasted, the fitting in of the pile and the masonry of the first layer was rapidly proceeded with. Quoins of hard wood were continuously intercalated between the caisson and the rock, and the caisson put in communication with the open air so as to continue the building. Contrary to expectation, the weight of the caisson was not sufficient to insure the staunchness of the method of jointure, of which mention has been made, and a slight layer of beton had to be put all round to the depth of 0.10 to 0.15 centim. This done, the caisson was pumped out by the same machine, and 10 or 15 minutes work per hour was enough to keep it dry. When open air work was required the two ends of the roof were taken down, the sluices and the rest of the roof were left standing. A few nuts had only to be unscrewed and this work was done in half an hour.

The piles made by this system cubed respectively 58.32 m. and 73.48 m. The average cost of the cubic meter came to 318 fr. This high cost was caused by the small depth of the foundation (1.95 m. and 2 meters), which might have been far greater without much more cost.

Besides this a new engine had to be built.

THE HISTORY AND STATISTICS OF AMERICAN WATER-WORKS.*

BY J. JAMES R. CROES, M. AM. SOC. C. E.

(*Continued from page* 295.)

XLIII.—SPRINGFIELD.

Springfield, Massachusetts, is on the east bank of the Connecticut River, in lat. 42° 6′ 10″ N., long. 72° 31′ 12″ W. The western part of the city is level, the eastern part is on high ground rising gradually from the river valley. Mill River runs on the south side of the city.

Settled in 1636 and first called Agawam, its name

* September, 1876.

was changed in 1640 and in 1852 it was incorporated as a city.

In 1843, the population being 11,000, Charles Stearns built a reservoir on the site of the present Lombard reservoir, and laid 8 miles of wooden logs, bored to 7, 6 and 4-in. diameter.

In 1845 the works were enlarged and the Springfield Aqueduct Company organized; they built the "Lombard," "Heywood," "Chapin" and "Worthington" reservoirs.

The number of takers at this time was 700, and the annual water rents amounted to $2,700. The company enlarged its works from time to time, but the supply was always inadequate. In 1867 the wood pipes were replaced by wrought-iron and cement, the east Van Horn reservoir was constructed, which was estimated to contain 45,000,000 gallons, and the Lombard reservoir was subsequently enlarged, and the west Van Horn reservoir built.

The first action taken by the city was in 1860, when a well 20 ft. deep and 10 ft. diameter was sunk, the flow of which was estimated to be 50 gallons per minute.

In 1860 a private company known as the City Aqueduct Company was incorporated, which, in this year, laid 1,950 ft. of 7-in. pipe and a brick drain or gathering gallery, along the base of the hill. The flow was about 40 gallons per minute. This awakened much opposition from residents on the hill, whose wells it drained, and whose trees suffered from want of moisture. The following year it was purchased by the city for $2,921.12 and abandoned.

In 1873, works were constructed by the city after the plans of Phinehas Ball, C. E., taking water from Broad and Higher brooks, whose drainage area is about 6.7 square miles, and impounding it in the Cherry Valley reservoir of 445 acres water surface at 402 ft. above the city datum plane.

The reservoir is formed by two earth dams. The Cherry Valley dam is at the outlet of a tributary of Broad Brook, and the Ludlow dam in the ravine on the divide between the drainage areas of Higher and Broad brooks.

The foundation of Cherry Valley dam begins on compact bluish hard pan. The bank was built of this material in 18 and 24-in. layers, each layer being flooded with a thin film of water, on which the next layer was dumped and driven over by teams. A heart wall of rubble masonry, 18 in. thick and 1,297 ft. long, comes to within 2 ft. of the surface of the bank, and is protected from frost near the surface by a dry rubble wall on each side of it, 2 ft. in depth from the top and 18 in. thick.

The dam is 25 ft. wide on top with slopes of 2 to 1, 39 ft. high above the natural surface and 47.6 ft. high above the lowest point of excavation, 2,352 ft. long, 1,521 ft. of which ranges from 3 to 5 ft. in height. The waste pipe is 20 in. in diameter laid, in stone masonry, and has a gate at each end. The inside slope is covered with rubble paving, 12 to 29 in. in thickness, the interstices filled with blue clay. The over-fall masonry rests on ledge rock and is 34 ft. long.

The Ludlow dam is 496 ft. long with a heart wall of rubble masonry 3.33 ft. wide with 6-in. concrete core. It is 35 ft. wide on top, 18 ft. high above the natural surface and 22 ft. high above the foundation.

A masonry gate-house is built in the dam from which a 30-in. cast-iron pipe is laid. A short distance above the Ludlow dam a dry rubble wall was built for holding in place a quantity of sand and an open space 100 ft. in length for filter screens. The space between the dam and the filter is four acres in extent, and was covered with clean sand. The filtering materials are placed in a duplicate set of vertical movable boxes made of oak plank. The filtering material is wood "Excelsior," and acts only as a mechanical filter. The thickness of material is 28 in. or 14 in. in each box. A derrick on a bridge over the filter raises and lowers these boxes into place. This filtering apparatus appears to have been used in 1875, but no mention of it is made in later reports.

The reservoir is centrally situated between the Higher and Broad Brook water sheds, and the water from these streams is conducted to it by canals. The canal to Higher Brook is 5,278 ft. long and has a grade of 3.7 ft. to the mile. The Broad Brook canal is 11,960 ft. long and has a fall of 1 ft. in this distance. It is 8 ft. wide at bottom and 6 ft. deep, with slopes of 1½ to 1.

In 1877 a waste channel of masonry fitted with iron gates was built through the Cherry Valley dam at the south end, through the over-fall and the bottom of the inner slope of the dam was covered with additional embankment.

The inner slope of the Ludlow dam was covered with loam, with the object of silting up all crevices in the gravel and preventing a leakage which had appeared below the dam and caused some uneasiness. Three overflows were constructed in the Broad Brook canal.

The main conduit to the city is 24 in. in diameter, 56,410.5 ft. long, 3,736 ft. of which, from Ludlow dam to Higher Brook, is of cast iron. The Chicopee River is crossed at Indian Leap by a bridge of 168-ft. span, the upper chords of which are two tubes 26 in. in diameter, 12 ft. apart which form the aqueduct. They are made of ⅜ in. boiler plate, riveted, and were lined with cement after erection. This bridge was designed and built by John R. Smith, C. E.

The rest of the conduit pipe is of wrought iron, lined and covered with cement laid on by hand after the pipe was in the trench. On being first filled many leaks occurred in a section of this pipe about 2,000 ft. long, where the ground was very firm and of good gravel. They were attributed to the fact that this part of the pipe was laid in very hot weather, and the cement at the joints set too quickly.

The section of cast-iron pipe gave great trouble from its having been laid in quicksand and settling. It was raised and laid on timbered foundation without interrupting the flow of water. This work of repairing was continued for four years.

There are two distinct services. The high service is supplied directly from the Cherry Valley reservoir, and the low service is supplied from the high by a regulator valve, and also through the Van Horn and Lombard reservoirs. The upper Van Horn reservoir has an area of 9.5 acres, a depth of 24 ft. and a capacity of 28 million gallons. The lower Van Horn reservoir has an area of 18.5 acres, is 30 ft. deep and contains 73.6 million gallons. The Lombard street reservoir has an area of 3 acres, is 23 ft. deep and contains 9 million gallons. All have their water surface at 198.5 ft. above the city datum.

The distribution pipes are partly of cast iron and partly of wrought iron and cement; 63.93 miles are in use, from 2 to 24 in. in diameter, 19 miles of which are of less than 6 in.

In December, 1880, there were in use 381 fire hydrants, 25 fire reservoirs, 3,290 taps and 44 meters. The use of meters began in 1878.

The population in 1870 was 26,703, in 1880 it was 33,340.

The daily consumption is not given in the reports. The cost to December 1, 1880, was $1,216,847.53. In 1880 the cost of maintenance, exclusive of interest and construction, was $10,008.31, and the revenue $79,280.92.

The works are under the control of a Board of three Water Commissioners. Phinehas Ball C. E. designed the works, and they were carried out under his superintendence and that of Geo. A. Ellis, C. E., City Engineer, who is engineer and registrar of the works at the present time. J. C. Hancock is the superintendent.

XLIV.—SALEM.

Salem, Massachusetts, in lat. 42° 34′ N, long. 70° 54′ W, is chiefly on a low tongue of land, formed by two small inlets of the sea. Settled in 1626, its population in 1796 was about 8,000, when Daniel Frye dug a well on Gallows Hill and supplied water from it to several consumers through wooden pipes.

In 1807 an association of five members, styled "The Proprietors of the Frye Aqueduct," was formed, taking water from this well. In 1809 there were 12 takers, and in 1852 the company expired.

A second company was organized in December, 1796, which was the beginning of the "Salem Aqueduct." Their first works consisted of a fish hogshead sunk in a spring on Gallows Hill, and wooden pipe of 3-in. bore. In 1798 they built a reservoir on Gallows Hill 10 ft. deep and 24 ft. square.

The works were extended from time to time, but each extension was followed by complaints of scarcity of water. In 1834 a line of 6-in. iron pipe was laid down.

In 1850 16,165 ft. of 12-in. iron pipe were laid to "Spring Pond" and a reservoir built of 652,000 gallons capacity. The company after this replaced their wooden pipe with iron. In 1859 they had laid 40 miles of pipe. In 1865 a connection was made with Brown's Pond.

The complaints against this company were frequent. At times the water was entirely shut off from the manufactories. The stock always paid large dividends, but little money was expended from the earnings for improvements.

In 1865-69 works were built by the city after the plans of James Slade, C. E. Water is taken from Wenham Lake, which has a water shed of 2.7 square miles, an area of 320 acres and an extreme depth of 58 feet. It is fed by springs from the bottom and has no entering streams. The bottom is free from mud and vegetation and is of clean quartzose sand. It is surrounded by a smooth, gravelly margin. The supply is taken from the south end, where the shore is bold and the water deep.

A 36-in. cast-iron pipe, with a bell mouth turned up and grated, beginning 32 ft. from the shore, conducts the water 175 ft. to a masonry gate chamber 10×8 ft., from which a brick conduit 10×7 ft. and 26 ft. long, leads to the pump well, which is 31.75×10 ft. inside, built of stone masonry, lined with 12 in. of brick, and resting on a timber and plank platform covered with 2 ft. of concrete. Quicksand was encountered in the excavation. A Worthington compound engine of 5 million gallons capacity lifts the water 114 ft., through 5,600 ft. of 30-in. cast-iron pipe, to the reservoir on Chipman's Hill, which is built in excavation and embankment, is 400 ft. square and 20 ft. deep, and contains 20 million gallons, with its surface 142 ft. above mean tide. A puddle wall is built in the centre of the bank, stepped down the slopes and carried 2 ft. thick over the bottom, where it is covered with 1 ft. of gravel and a stone paving. The inner slopes are covered with 12 in. of gravel, on which is a dry stone wall 15 in. thick.

At the centre of the westerly bank is the influent, and in each of the southerly corners is an effluent pipe 20 in. in diameter and 2 ft. above the bottom. They are surrounded with screen cribs containing screens 8 ft. high. The tops of the cribs are solid and have a trap door for access to the pipe. The pipes pass through the bank turning downward and then following the clay puddle. Each pipe is supported on a brick pier. Two walls of masonry 2 ft. thick are laid across the be-