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“Reinforced-Concrete Sewers and Conduits, in the United States of America.”

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UNTIL within quite recent years, American practice in the construction of sewers and conduits differed only very slightly from that of this country, the differences being entirely in matters of detail. During the past few years, however, the use for this purpose of reinforced concrete moulded in place on suitable centering has been widely adopted in the United States, and has proved eminently successful.

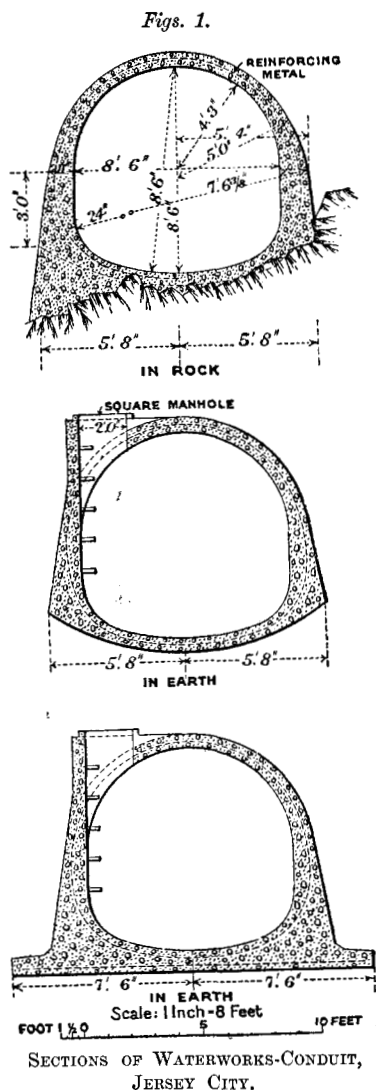
The following are some of the advantages claimed for this method of construction :—

- (1) Economy in cost.
- (2) Rapidity in construction.
- (3) Very low cost of maintenance.
- (4) Great hygienic value (a concrete sewer can be easily cleansed and disinfected, and does not harbour microbes).
- (5) The expansion and contraction, under varying temperatures, of the different materials composing the sewer is practically the same.
- (6) The concrete does not deteriorate, but increases in strength and hardness, with age.

In this Paper the Author describes a number of sewers and conduits which have been constructed on this principle in American cities during the past few years.

Waterworks Conduit, Jersey City, N.J.—The most important example of a reinforced-concrete conduit in America is the conduit built in 1903 for the new water-supply of Jersey City. This conduit is 8 feet 6 inches in width by 8 feet 6 inches in height from the invert to the under-side of the crown of the arch, *Figs. 1*. It is practically elliptical in cross-section, with the haunches and bottom forming an inverted arch, and it is nearly 4 miles in length. The sections vary according to the cutting, some being in earth and others in rock.

In each case the reinforcement consists of twisted square steel bars, viz., circumferential bars, $\frac{3}{8}$ inch square, spaced 1 foot apart, and longitudinal bars, $\frac{1}{4}$ inch square, spaced 2 feet apart. All the bars are wired together at the intersections and are spliced by 1-foot laps wound with wire. The heavy rock-section is about 826 feet and the embankment-section 420 feet in length. The concrete was composed of 1 part of cement, 2 parts of sand, and 5 parts of $1\frac{1}{2}$ -inch broken stone. Before this conduit was constructed, in May, 1900, a test-section 10 feet in length was built, and was tested in the following manner: Three saddles of timber were set on the crown of the arch, one in the centre, and one at each end, and a layer of nine rails was laid on these saddles. A level having been set up to determine any deflection, more rails were added, one by one. The actual test was commenced at 2.45 P.M., and at 5.28 P.M., with a load of $21\frac{1}{2}$ tons, fine horizontal cracks began to appear all along the extrados, but no measurable deflection took place. When the load had been increased to 25 tons, three rails, weighing approximately 1 ton, were dropped on the rails on top of the arch, over one end of the latter. The cracks were slightly widened, and new fine cracks appeared at the intrados and at the haunches, running along inside the section. The clear height of the section was measured immediately before the commencement of the test, and was measured again 24 hours after the last rail was added.

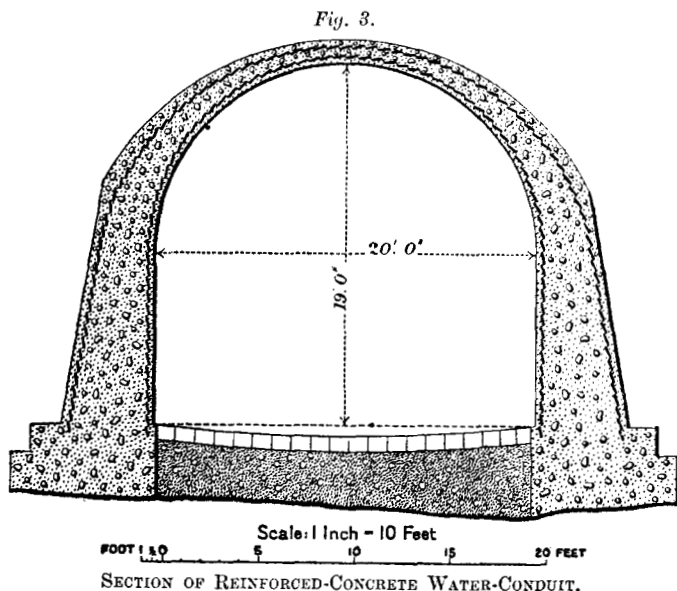
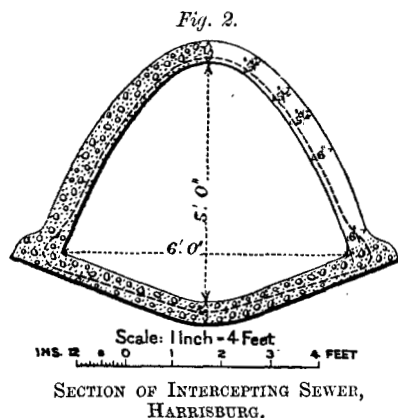


The total deflection at the crown of the arch was found to be $\frac{7}{16}$ inch, and it had not increased under the constant load when

again measured one month later. This conduit was designed by Mr. E. W. Harrison, Consulting Engineer to the Jersey City Water-Supply Company.

Intercepting Sewer, Harrisburg, Pa.—A transverse section of this sewer is shown in Fig. 2. The sewer is 3 miles in length and is constructed of reinforced concrete. It is partly 5 feet in width and partly 4 feet in width of section, and has a parabolic roof and an invert

composed of a circular curve and two tangents. In the invert the thickness of the concrete varies between 5 inches and



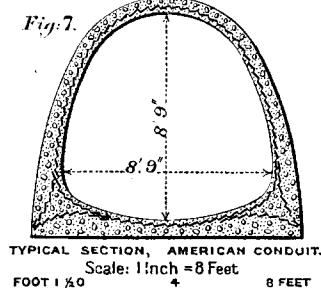
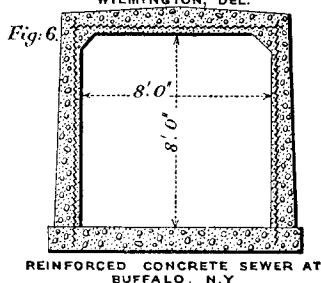
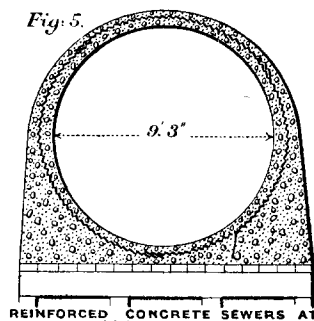
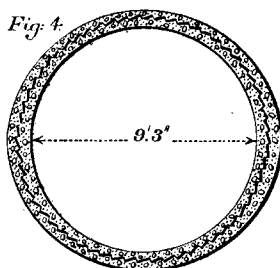
6 inches, and in the roof it varies between 5 inches at the crown and 9 inches at the base. The reinforcement used was expanded metal,

with a lap of at least 2 inches at every seam. The concrete used was composed of 1 part of Portland cement, $2\frac{1}{2}$ parts of sand, and $4\frac{1}{2}$ parts of ballast broken to pass through a $1\frac{1}{2}$ -inch ring. The invert was finished with a coat of Portland-cement mortar, $\frac{1}{2}$ inch in thickness, composed of equal parts of cement and sand, applied before the concrete was set. This sewer was designed by Mr. James H. Fuertes, of New York, and the work was executed by Mr. S. M. Neff, of the same city. The excavation was in gravel containing a considerable quantity of subsoil water.

Water-Conduit for an American Railroad Company.—A reinforced-concrete water-conduit constructed by one of the American railroad companies is illustrated in Fig. 3. It was necessary in the construction of this conduit that there should be a minimum thickness of concrete at the crown, and this necessitated the insertion of two layers of expanded metal so as to make the culvert of sufficient strength to carry railroad traffic.

Concrete Sewers at Wilmington, Del.—A section through a reinforced-concrete sewer at Wilmington, designed by Mr. T. Chalkley Hatton, is shown in Fig. 4. The sewer varies between 4 feet 9 inches and 9 feet 3 inches in diameter, and is 7,500 feet in length. It was constructed for the purpose of conveying the sewage from a portion of this city. A section of another reinforced-concrete sewer at Wilmington is shown in Fig. 5.

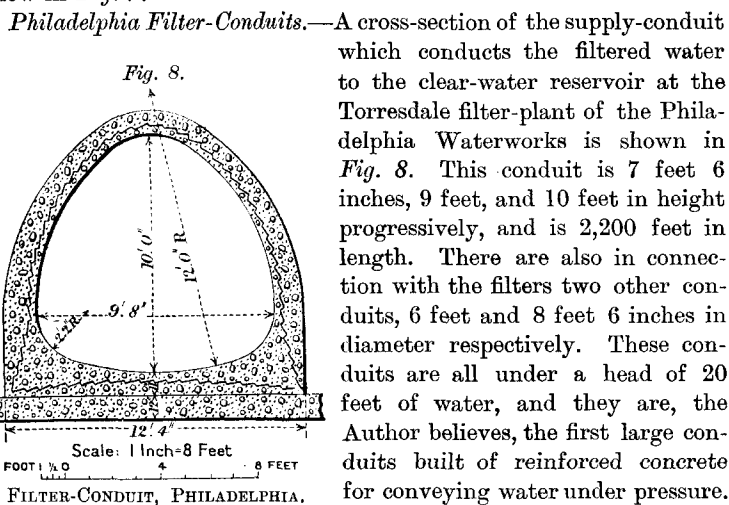
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This sewer is 9 feet 3 inches in diameter and 1,726 feet in length, and was also designed by Mr. T. Chalkley Hatton.

Sewer at Buffalo, N.Y.—A sewer which was constructed some years ago by the Lackawanna Steel Company, at Buffalo, is illustrated in *Fig. 6*. It is used by that Company for discharging water from the rolling-mills and other parts of their extensive plant. It carries all kinds of surplus liquids from their factory-grounds to the river. This sewer is nearly a mile in length, and was built on old ground, over which a considerable thickness of earth was laid, upon which railroad-tracks and buildings were located. The sewer was designed by Mr. C. R. Neher.

A typical section of an American reinforced-concrete conduit is shown in *Fig. 7*.



Philadelphia Filter-Conduits.—A cross-section of the supply-conduit which conducts the filtered water to the clear-water reservoir at the Torresdale filter-plant of the Philadelphia Waterworks is shown in *Fig. 8*. This conduit is 7 feet 6 inches, 9 feet, and 10 feet in height progressively, and is 2,200 feet in length. There are also in connection with the filters two other conduits, 6 feet and 8 feet 6 inches in diameter respectively. These conduits are all under a head of 20 feet of water, and they are, the Author believes, the first large conduits built of reinforced concrete for conveying water under pressure.

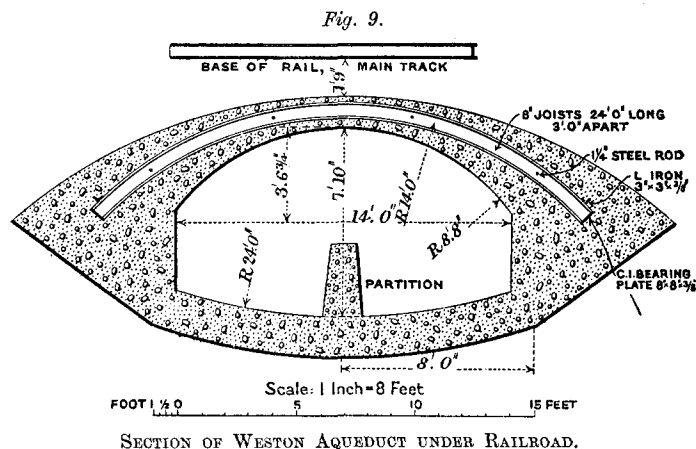
The reinforcement consists of ex-

panded metal, two layers of 6-inch mesh sheets of No. 4 Standard gauge being inserted. The concrete was composed of 1 part of cement, 3 parts of sand, and 5 parts of $\frac{3}{4}$ -inch broken stone, but the inside face, to a depth of 1 inch, consisted of 1 part of cement and 1 part of granolithic grit. The conduits were built in sections 12 feet to 13 feet in length and as monoliths, a groove being left in the end of the section, into which the next section is bonded. The centering was allowed to remain in place about 60 hours after the concrete had been laid. The forms were covered with iron sheets, which were cleaned and oiled each time before using. The sheet-iron covering proved to be very advantageous, as it gave perfectly smooth work, and protected the forms. The rate of

progress was about one section of each of the conduits every two days, being controlled entirely by the excavation. The trench for the discharge-conduit is 34 feet in depth, and for the supply-conduit 22 feet; the material was mostly sand and gravel containing a considerable amount of water. The water was removed from the trench by a sub-drain laid under and in advance of the conduit, and draining into a sump at one end or on one side of the trench.

The concrete was composed of 1 part of Portland cement, 3 parts of sand, and 5 parts of $\frac{3}{4}$ -inch broken stone.

Against the face of the form, to a thickness of 1 inch, was laid granolithic mixture composed of 1 part of Portland cement, 1 part of sand, and 1 part of granolithic grit. This mixture was made as thin as grout, and was poured into the space between the forms and



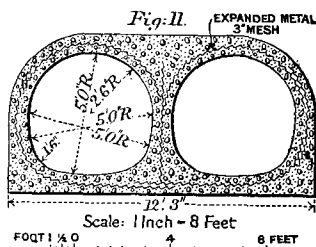
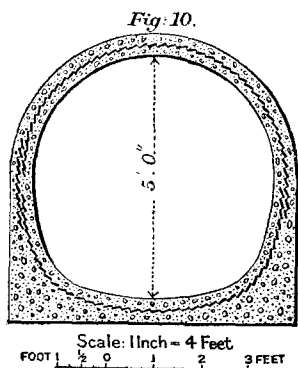
a metal sheet, set to give the thickness desired; this was done directly in advance of a layer of concrete, the metal sheets being drawn gradually during the ramming of the concrete. The workmen employed, other than the foremen and carpenters, were ordinary labourers, and the work was so smooth that no finishing was required.

Mr. William C. Haddock, Director of the Department of Public Works, had general executive charge of the works for the improvement of the water-supply, the engineering-work being carried out under the supervision of Mr. John W. Hill, Chief Engineer of the Bureau of Filtration.

Weston Aqueduct, Boston, Mass.—In constructing the large Weston Aqueduct for the water-supply of Boston, it was necessary at one

point to carry the structure under the tracks of the New York, New Haven and Hartford Railroad. The normal section, 10 feet in width by 9 feet 6 inches in height, was therefore flattened as shown in *Fig. 9*, making it 14 feet by 7 feet 10 inches, and the roof of this flattened section was reinforced throughout with 8-inch curved steel joists, 24 feet in length, spaced 3 feet apart, centre to centre, and tied together longitudinally by four $1\frac{1}{4}$ -inch steel rods, the ends of the joists resting on cast-iron bearing-plates, 8 inches square by $\frac{3}{4}$ inch in thickness.

Cedar Grove Reservoir Conduit, Newark, N.J.—In the construction



CEDAR GROVE RESERVOIR CONDUIT.

of the Cedar Grove Reservoir, a new storage-reservoir for the Waterworks Department of the city of Newark, a certain amount of conduit-work, partly of single and partly of double section, was required. This conduit was constructed in reinforced concrete, and is 5 feet in diameter of section. It is in two lines, namely, a single conduit 4,000 feet in length (*Fig. 10*) and a double conduit 1,500 feet in length (*Fig. 11*). The reinforcement consists of a circumferential ring of expanded metal of No. 10 gauge and 3-inch mesh, with lapped joints. The concrete used was composed of 1 part of cement, 2 parts of sand, and 5 parts of $1\frac{1}{2}$ -inch broken stone. These conduits are described in detail in the Report of the Tenth Annual Convention of the American

Society of Municipal Improvement, in a Paper by Mr. Morris R. Sherrerd, Engineer of the Waterworks Department of the city of Newark, from which the following information is derived:—

The conduits are at times subjected to the pressure of a head of water of 45 feet, and therefore, before finally adopting the reinforced concrete form of construction, sections of both single and double conduit were built and subjected to pressure. The double conduit was built practically as a monolith, but the construction of the single conduit was interrupted, and a horizontal joint was made in the section. Both of these sections were tested under hydraulic

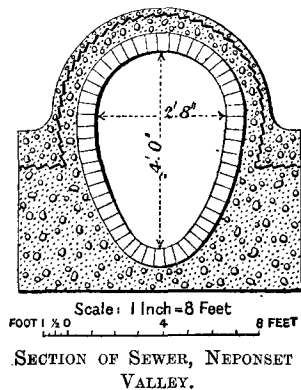
pressure, wooden heads being bolted to the ends so that the sections could be filled with water. The single conduit gave way at the horizontal joint under a pressure supposed to have been about 15 lbs. per square inch. The double conduit was tested up to a pressure of 35 lbs. per square inch, and showed no signs whatever of weakness. This section has been incorporated as part of the permanent work. After a little experimenting, the conduits were built in monolithic masses as easily as they could have been built in any other way, an expansion-joint being made at the end of each day's work, which was approximately 30 feet length of conduit. These joints opened about $\frac{1}{8}$ inch without serious leakage. The conduits cost £1 4s. 3d. per foot for a single line and £2 8s. 0d. per foot for a double line of 60-inch conduit, as against £1 17s. 3d. per foot for a single line, and £5 14s. 6d. per foot for a double line of cast-iron pipe of the same size, exclusive of excavation in both cases. The total saving effected by the use of reinforced concrete amounted to £8,166 13s. 0d.

Sewer Reconstruction in Boston, U.S.A.—Some four or five years ago a difficulty was met with in the building of a large sewer in Neponset Valley, in Boston, at a location where it was not possible to secure sufficient room for earth-filling on the top of the sewer without going above grade-line.

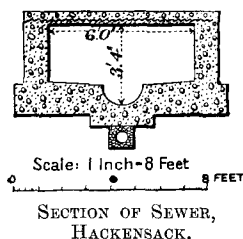
This lack of filling resulted in continual bursting of the sewer by water-pressure. The section in question ran through private property, and the owner would not permit the necessary extra filling to be added. The Chief Engineer of the Metropolitan Sewage Commission, Mr. William H. Brown, after careful investigation of the subject of expanded steel and concrete, decided to make a trial of a reinforced-concrete cover for this sewer. This work has been carried out as illustrated in *Fig. 12*, at comparatively small cost, and the arch of the sewer has proved sufficiently strong to withstand safely the pressure which caused the destruction of previous arches. In other parts of Boston similar difficulties were met with, and were overcome by the adoption of the same methods and with the same satisfactory results.

Sewer Reconstruction in Hackensack, N.J.—The difficulty of securing

Fig. 12.

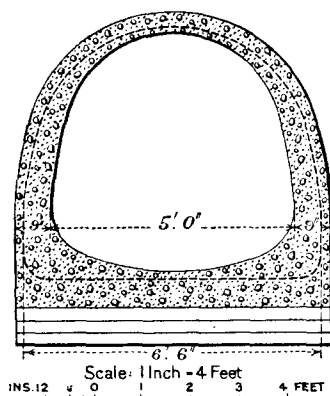


a permanent roofing for a wide shallow sewer in Hackensack, New Jersey, was overcome by the engineer in charge of public work in that city, by the adoption of expanded steel and concrete, as illustrated in *Fig. 13*. The location of the sewer rendered it necessary, in order to carry the volume of water required, to make the section very wide and shallow. The sewer had a fall of only 1 foot in its entire length of 800 feet.

Fig. 13.

mesh and No. 10 gauge, used in its construction amounted to more than 50,000 square feet.

In the Author's opinion, it is fair to assume that in sewer and conduit construction in America, reinforced concrete is cheaper than brick or stone for all sections not less than 4 feet in diameter; otherwise it would not have been so largely used as it has been.

Fig. 14.

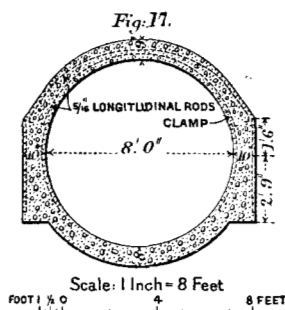
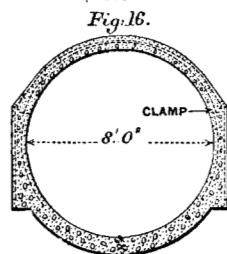
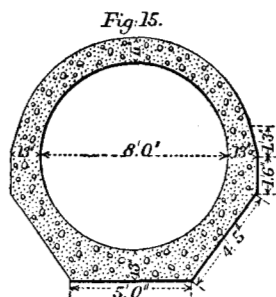
SECTION OF CONDUIT, SYRACUSE.

Sewer at St. Joseph, Mo.—At St. Joseph, where the sewage and storm-water discharges into the Missouri River, the main sewers, which have been in existence for 25 years, were, up to the year 1902, with few exceptions built entirely of brick; the exceptions are those built of native limestone, smaller sewers being built of vitrified pipe. In 1902, owing to the rapid growth of the city, it was found necessary to extend some of these main sewers, and some of the extensions

were carried out in concrete and others in reinforced concrete, on the Parmley system. Interesting particulars as to the relative cost of these two systems have been furnished by Mr. W. H. Floyd, Junior City Engineer of St. Joseph. Sections through sewers of the two types referred to are shown in *Figs. 15, 16, and 17*. It will be seen that each of the sewers is circular in cross-section and 8 feet

in diameter. The concrete sewer required 1·16 cubic yard of concrete per lineal foot, as compared with 0·63 cubic yard of concrete and 17·1 lbs. of steel per lineal foot required for the reinforced-concrete sewer. The contract price for the 8-foot sewer built of plain concrete, complete, exclusive of the cost of excavation and filling, was £1 8s. 2d. per lineal foot; whilst that for the 8-foot reinforced-concrete sewer complete was £1 5s. 8d. per lineal foot. The steel reinforcement consisted of transverse bars and longitudinal rods placed as shown in the cross-section, *Fig. 17*. The transverse bars are $\frac{3}{8}$ inch by $\frac{1}{2}$ inch in section, and are spaced 2 feet apart, centre to centre. The longitudinal rods are $\frac{3}{8}$ inch in diameter and are interlaced between the transverse bars. The sewer-invert was first built up to the springing-line of the arch; pieces of the transverse bars long enough to extend 1 foot 6 inches above that line were placed in the haunches of the arch after the centering had been fixed for the upper half of the sewer; and the arch-bars were carefully laid in position and fastened to the side-bars with clamps, as shown in *Fig. 18*. The longitudinal rods were wired to the arch-bars and the work was then ready to receive the concrete, which was mixed very wet in order to allow it to flow well under and around the steel bars.

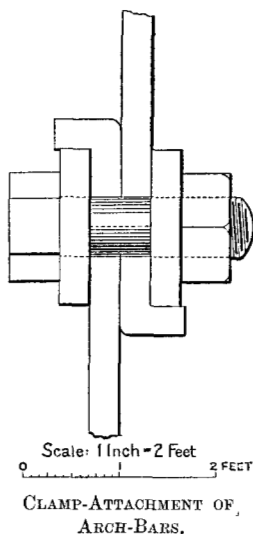
Another 8-foot reinforced-concrete sewer, intended to act as a storm-water sewer, has been constructed in this city. The sewer is 3,900 feet in length and is also built on the Parmley system. Where it passes under the railroad tracks the section is increased in strength, 1·21 cubic yard of concrete and 17·3 lbs. of steel per lineal foot being required. The thickness of the concrete at the crown of the arch, as is shown in *Fig. 17*, is 9 inches,



SECTIONS OF SEWERS AT
ST. JOSEPH.

whereas in the section previously referred to it was 6 inches at the springing of the arch and 10 inches at the invert. These sewers were designed and built under the direction of Mr. W. H. Floyd.

Fig. 18.

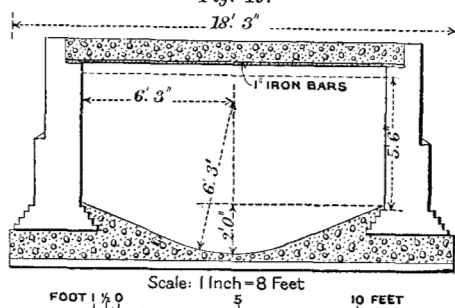


Drainage Canals, New Orleans, La.—

In carrying out this work reinforced concrete was extensively used for roofing the canals. A section through one of these canals is shown in *Fig. 19*, and it will be seen that the canal has a flat roof formed of reinforced concrete, that the side-walls are built of brick, and that the invert is formed of ordinary concrete. The reinforcement of the roof consisted of $\frac{1}{2}$ -inch corrugated bars, the concrete lining being composed of one part of Portland cement to five parts of gravel. In the particular section shown, the reinforcement-bars are set 1 inch from the bottom and are spaced 4 inches apart. The canal varies in

width, and the following are the thicknesses of concrete used for various spans:—

Fig. 19.



SECTION OF DRAINAGE-CANAL, NEW ORLEANS.

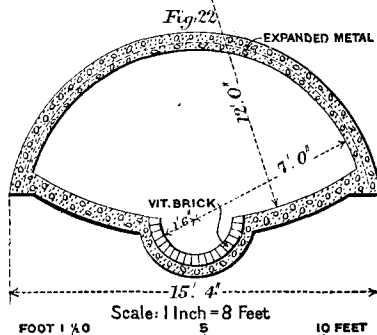
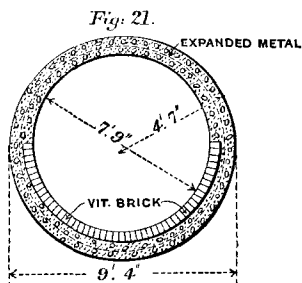
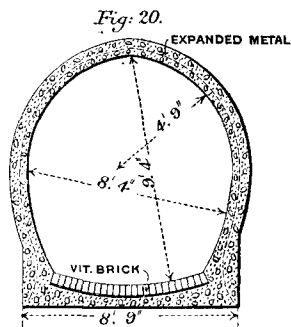
Span.	Thickness of Concrete.
Feet.	Inches.
5	5·85
6	6·58
7	7·26
8	7·92
9	8·59
10	9·23
12	10·61
13	11·23

Sewer at Lancaster, Pa.—Transverse sections of reinforced-concrete sewers at Lancaster are shown in *Figs. 20, 21, and 22*. These sewers were designed and carried out by Mr. S. M. Gray, and previously to their construction Mr. Gray made careful comparisons

of the cost of the types of sewers here illustrated and of brick sewers, with the result that the former proved to be cheaper. Moreover, owing to the surface of these reinforced-concrete sewers being so much smoother than that of brick sewers, and consequently causing less friction, they are 2 inches smaller in diameter than brick sewers of the same capacity. It will be seen that *Fig. 20* represents a sewer of horseshoe section; *Fig. 21* a circular sewer, and *Fig. 22* a sewer of semicircular section. Each of these sewers was reinforced with expanded metal of No. 10 gauge and 3-inch mesh, and it will be seen that the invert in each case is formed of vitrified bricks.

General Methods of Construction.—The concreting of conduits and sewers in America is done in sections. The length of section usually chosen is that which can be completed in a day's work without any portion of the concrete becoming set before fresh concrete is joined to it, and this length, of course, varies with the size of the conduit.

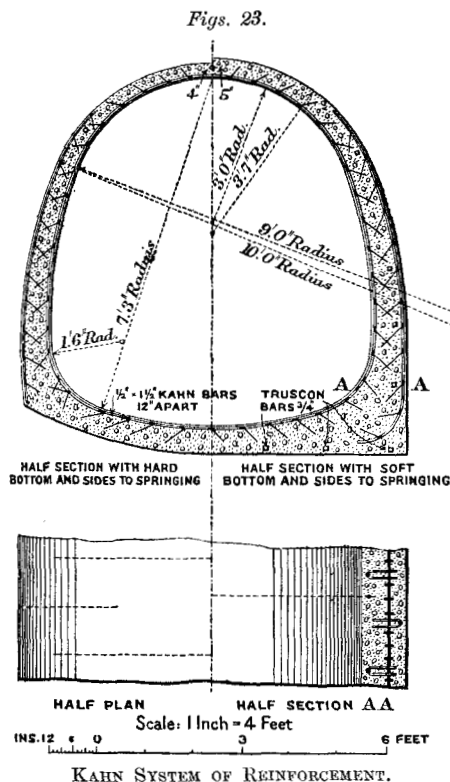
In the Cedar Grove Conduit, previously referred to, one portion of which was single and another portion double, it was found that a length of about 32 feet of the twin conduit could be built in a day. The most general practice in ending the day's work is to finish the section with a groove or mortice, in order that it may be



SECTIONS OF SEWERS AT LANCASTER.

easily bonded with the work of the next day. It is the common practice in America to use a very wet mixture of concrete in the construction of these conduits, so as to secure a dense and compact product, especially where the conduit has to carry water under pressure.

In the construction of the Jersey City conduits already described, the centering was made in sections 12·5 feet in length, consisting of

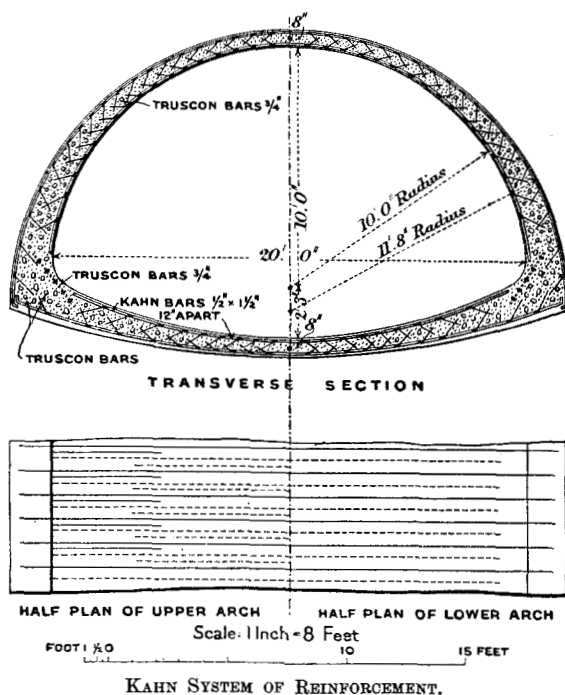


eleven segments. These sections were left in place about 48 hours and occasionally they were greased with vaseline. At the end of each day's work a groove was formed in the face of the concrete to enable it to be bonded with the succeeding day's work. Practically no finishing was required on the inside face of the conduit, so well was the work executed. The speed of construction also is noteworthy; between 25 July and 14 November no less than 18,500

feet length of conduit was built; and on one section 2,586 feet length of conduit was built in 65 days by a gang of thirty-eight men—an average of 39.8 lineal feet per day.

Reinforced-Concrete Pipes for Sewer and Conduit Construction in America.—The manufacture of reinforced-concrete pipes in America for sewer and conduit construction forms an important branch of sanitary work. In Cleveland about $3\frac{1}{2}$ miles of new intercepting sewers have been constructed in this way during the past 3 years, one sewer

Figs. 24.



being 3 feet 6 inches in diameter; and upwards of 4 miles of other sewers, ranging between 5 feet and 12 feet in diameter, have been completed. These and other similar pipe-sewers in America have been constructed very largely on the Bonna system. The process of casting Bonna pipes is briefly as follows:—The rings of the inner reinforcement are first erected and adjusted on a mandrel, and the longitudinal bars are then attached to them; the interior steel tube is then constructed by means of special machines for bending the

sheets and forming the joints. The outside reinforcement is erected in exactly the same manner. The two reinforcing skeletons, with the steel tube between them, are then set on end on wooden templates, a hollow cylindrical steel mould is placed around them, a collapsible steel mandrel is placed inside, and the liquid mortar is poured in. For placing the moulds and pouring in the liquid mortar, and for handling the pipes, a travelling platform and crane are usually employed.

In the Cleveland sewers, previously referred to, the steel skeleton consisted of bars 2 inches by $\frac{1}{2}$ inch, 15 inches apart, centre to centre, with a few longitudinal bars, $1\frac{1}{2}$ inch by $\frac{1}{4}$ inch. The metal, which was all accurately shaped in the mill, weighed about 93 lbs. per foot run, and the concrete arch is 12 inches in thickness at the crown, and 15 inches at the springing. In jointing these pipes the joints are coupled together by an iron band run around and through the loops of the iron bars, which are embedded in the cement. The cement adhering to the iron bands or ring of bitumen, as the case may be, makes the joint as strong as the pipe itself.

The Monier pipe, which has been largely used in Germany, and the Bordenave pipe, which has been widely adopted in Europe, are very similar to the Bonna pipe, which has been adopted in America.

Typical sections of sewer construction, as carried out in America under the Kahn system of reinforcement, are illustrated in *Figs. 23* and *24*.

The Author has endeavoured in this Paper to show that the tendency in America at the present time is to construct sewers and conduits in reinforced concrete, and having had considerable experience in the use of this material, he is convinced that this method of sewer and conduit construction, at any rate in America, will be more and more generally adopted.

The Paper is accompanied by seven sheets of drawings, from a selection of which the Figures in the text have been prepared, and by two photographs, which may be seen in the library of the Institution.