METHODS OF CONCRETE SEWER CONSTRUCTION

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Several varieties of design and construction of concrete sewers are described which, with the photographs, show the adaptability of concrete to such construction, making many economies possible in materials and labor as well as in special forms of construction and of transmission of materials which are not possible with other materials. The descriptions of actual work done make the article specially practical and valuable.

Some of the characteristics of concrete lend themselves splendidly to sewer construction, but no material is so perfect as to be ideal in all cases. Concrete, in other words, has its faults as well as its advantages. Prominent among its faults is its permeability to water under pressure and its lack of tensile strength. These defects are both of them more or less capable of elimination. Steel reinforcement supplies to some extent a means of combating tensile weakness and is rather peculiarly fitted for this duty because of the fairly close correspondence of its coefficient of linear expansion with that of concrete. Permeability may be fought by giving the concrete a maximum density. Unfortunately, density means an increase in the percentage of the most expensive ingredient, portland cement.

Concrete sewers may be built of concrete pipe or as concrete-lined excavation. In both cases the sewer must be strong enough to resist the crushing pressure on its arch of the weight of earth or other load on top of it and pressure in any other direction on account of water in the ground or compressible or movable soil, as well as pressure of water from within in case such pressure is possible for any reason.

In illustration of a portion of the foregoing remarks, may be cited the Sierren street storm sewer at San Antonio, Tex. The main line is made of concrete, some of it being 3½ and some 4 feet in diameter. Part of this line was given a reinforcement of wire mesh, part was not reinforced. Where the reinforcement was used, it weighed about 1 ton to, say, 185 linear feet of conduit. It was bent to shape by workmen using hammers, the resulting section being not a circle, but octagon. Steel forms were employed and the tube was cast in position. The typical section shows a cylindrical shell with a flat horizontal surface where the sewer rests on the soil. The trench in which this pipe was poured varied in depth from 6 to 12 feet. The concrete was similar to that made by the formula 1:2:4, the river gravel containing an excess of sand. Crushed limestone was used to offset this. This ability to use local materials in large part in making the concrete has done much to popularize it for sewer construction.

At Los Angeles, Cal., we have an example of a concrete pipe sewer over 5½ miles long. The pipe in this case was cast in sections above ground and then allowed a period for maturing which was 15 days. Steel forms were employed, and the sections cast were 3 feet in length, whatever the diameter might be. A fairly dense concrete was employed, following the formula 1:2:4. One-half mile or more of the sewer consists of 6½-inch pipe, and 5 miles of pipe, varying from 34 to 60 inches in diameter.

The joints were made by means of a cement mortar, 1:2 mixture. Heavy roofing paper or sheet iron was employed on the exterior of the sewer to provide a form for the grout. When all was ready, the grout would be poured from one side until it appeared on the other, when pouring would be completed from the other side. If, for any reason, the grout failed to appear as expected, the joint was dug out and the difficulty was removed. A 9-foot length of 6½-inch pipe, having a wall thickness of 6 inches, weighed 3,500 pounds.

At other points along this De La Brea sewer at Los Angeles, the size of conduit required was much greater, 1,249 linear feet having dimensions of 12½ x 9 feet, and 1,621 linear feet being somewhat smaller, 10 x 8½ feet. All of this larger size was constructed of reinforced monolithic concrete. On other sections, monolithic concrete, not reinforced was used for cross-sections of large but varying sizes. Part of the large construction consisted of invert and arch, the latter provided with numerous reinforcing rods.

An interesting instance concerned in the laying of pre-molded concrete shells occurred not long ago in Philadelphia. Two varieties of shell were used, a 36-inch circular shell and an egg-shaped shell, 50 x 12 inches in dimensions. The pipes A CONCRETE SEWER HERE DISCHARGES ITS ORDINARY FLOW OF SEWAGE INTO THE CHANNEL TO THE INTERCEPTING SEWER RUNNING OFF TO THE LEFT TOWARD THE SPECTATOR. WHEN SUFFICIENT STORM WATER COMES TO OVERFLOW THE DAM SEEN IN THE FOREGROUND, THE EXCESS RUNS OFF IN THE OVERFLOW SEWER UNDER CONSTRUCTION AT THE RIGHT. NOTE THE REINFORCEMENT IN THE WALLS WHICH WILL BE EXTENDED UP TO RECEIVE A FLAT TOP OR AN ARCH OF CONSIDERABLE RADIUS OVER THE WIDE SPACE AT THIS SEPARATION OF THE WATERS. NOTE THE METHOD OF SUPPORTING THE EXISTING VITRIFIED PIPE LINE DURING THE CONSTRUCTION OF THE NEW SEWER.
were in general made in short lengths of 4 feet each. The circular shell had a wall thickness of 4 inches. Triangular steel mesh was used for reinforcement. It was set concentric with the shell and 1/3 inch back of the interior surface. Similar mesh similarly placed was used in connection with the egg-shaped sections.

The forms were of metal and consisted of two cast-iron rings for top and bottom of the pipe length and of two sheet-steel shells for the body. Clamps and bolts held all together. The inner shell was provided with a horizontal shoulder formed of angle bar, upon which was placed a thin steel disc. This disc closed the interior of the mold and served as a table from which concrete might be worked into the form. The mode of providing for the projecting steel mesh at the socket end was as follows: The cast-iron ring for the socket end was laid on the working surface and the inner shell of the form put in place. A slot was provided in the cast-iron ring of such dimensions as to make it a convenient receptacle for the projecting reinforcement. The piece of mesh was now set in place in the slot and the latter was filled up with sand. The purpose of the sand was to prevent the entrance of concrete when the pipe was cast. The cylindrical shell of mesh was in one piece, being made from fabric wide enough for one length of pipe. One roll of the material weighed about 450 pounds.

The socket and spigot ends had such forms as would be produced by counter-boring in the one case and exterior recessing in the other, and when put together the continuity of the inner cylindrical surface was not interrupted. When the joint was prepared, the two parts fitted together with the projecting reinforcement between them. A hole was provided at the top thru which grout might be poured. In this way the upper part of the joint was sealed and reinforcement included in it.

The aggregate used in the concrete was made in proportions 1:2:4 from gravel or sand and trap rock crushed to a size varying from 1/2 to 3/4 in. The concrete was mixed rather wet so that it flowed readily into the form. It was put in place by an experienced man armed with a spade made from a steel plate which had been curved a trifle. The effective handle was about 7 ft. long. In spite of every effort in placing, air holes would sometimes form on the surface of the pipe. Paraffin oil was used on the forms to prevent adhesion of the concrete.

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Circular arch and invert with different radii and a low vertical wall between, as used in New York. Forms with wooden ribs, braces and lagging were used in this construction.

Outside of forms used in constructing the sewer shown in the preceding photographs showing the wooden lagging, the deformed bar reinforcement, circumferential and longitudinal, the method of housing house-connection pipes in place until concrete is poured and set, and the trench bracing.

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Some trouble was nevertheless experienced. A 12-hour vapor bath was tried, but some doubt had been expressed as to the desirability of using this remedy, because of the considerable difference in temperature between top and bottom.

The trenches were excavated about 1 ft. wider than the pipes. The depth was carried to a level about 3 in. lower than the point determined for the bottom of the sewer. Instead of resting the concrete shells directly on the soil, a concrete cradle of 1:3:4 mixture was provided. The cradle was broad enough to provide a curved rest 12 in. deep. How to seat the pipe on the cradle seems to have required experimentation. After some trial, the method adopted required the concrete cradle to be brought up to within about ½ in. of the proper level of the bottom of pipe. Three days or more were allowed for hardening. When all was ready for actually setting the pipe, a mortar was spread to the depth of ¾ in. and the pipe was settled upon it. The making of the joint then followed, whereupon the cradle was brought up to its required height.

The making of the joint was effected "by first overlapping the reinforcement projecting into the socket and pressing it into position, then applying a stiff mortar to the lower half of the socket from the inside of the pipe, and grouting the upper half from the outside thru the pouring hole at the top. The mortar was pressed thru the reinforcing until the lower half of the socket was completely filled, when it was troweled to a smooth finish; a steel band 6 in. in width was then sprung around the entire interior of the pipe and keyed tight to prevent the escape of the grout, the exterior being sealed with a coat of stiff mortar covering the joint on the entire upper half of the pipe and extending about 12 inches below its center. While the grout was being poured a heavy steel wire was worked in the joint to prevent choking and to expel the air. This was continued until the joint was completely filled and the grout was brought to the top of the pouring hole. The steel band was removed in 24 hours and the joint smoothed to a finish on a plane with the interior surface of the pipe." Both the mortar and the grout followed the formula 1:2.

As to relative cost of such sewers as compared with brick, it is interesting to note that several years prior to actual construction, but at a time when labor and material costs were about the same, bids were received for brick construction. The lowest bid for the circular 36-in. sewer was $7.95 per lin. ft. The lowest bid for concrete, the concrete bids being re-
ceived presumably about the time of construction, was $5.10 per lin. ft. of sewer. Here is a very substantial difference. However, for the egg-shaped construction, the lowest bids were about the same, the brick having a slight advantage. The prices included excavation, backfilling and repairing.

It is considered to be a bad condition when a reinforced concrete sewer develops any kind of cracks, even those as thin as hairs. There is then danger that the reinforcement will suffer corrosion. It should be remembered that the relation between concrete and steel is a two-fold one. The steel is there to furnish tensile strength; the concrete has the duty of protecting the steel. It is valuable then to know that experiments carried out for the benefit of the city of Philadelphia showed that a concrete cradle provided a much better support for reinforced concrete pipe than a bed of sand. The experiments covered both circular and egg-shaped shells, the latter having a flat base. The superiority was observed for both types, but was more pronounced in the case of the circular pipe. The loading against which protection was sought was similar to that of a backfill.

As to permeability—that is, liability to leakage—if concrete is properly made and in accordance with the formula, \(1:2.5\), no trouble should ensue for pressures amounting to 5 pounds per sq. in. That is, a constant head of ground water of 11 ft. is permissible. It was brought out in the permeability tests at Philadelphia that pressure on freshly poured concrete promotes water-tightness. The parts of the shells which constituted the upper halves when in the forms were found more permeable than the other parts. My suggestion, growing out of this, is to the effect that the forms should be so made as to make it possible to put the whole shell under pressure during the early period.

The Philadelphia experiments are thought to warrant placing the reinforcement (wire mesh) close to the inner face of the sewer. This remark is to be understood as applicable to circular sewer pipes 3 ft. or less in diameter and to egg-shaped pipe whose greatest diameter is no larger than 3 ft. The typical thickness of concrete over the mesh on the interior was 1\(\frac{1}{4}\) in. With reference particularly to the question whether this amount of concrete is sufficient to protect the...
The general mode of procedure was as follows: A concrete mixer with a steam engine and boiler shifts upon a track along one side of the trench. Dump cars bring up the material, each car having on board just about the right amount for one charge into the 3/4-yd. mixer. A charging hopper is swung down to receive the materials from a car. When the concrete has been mixed, it is chute to the point of use. The chute has two hinged sections which may be successively thrown up to shorten it. Naturally, the long chute is used when delivery has to be made low down in the trench, and the shorter lengths as the placing rises to the top of the arch. The contractor used wooden forms for the arch at the beginning, but later on used a type of form which consists of steel ribs and wooden panels, the latter being faced with steel sheeting. With the steel forms, the short length of sewer is poured in two operations. First, the invert is cast, wooden forms being employed. Then, the side and arch forms are put in place and the pouring is carried to completion. A 24-hour interval is allowed the invert for setting before the second operation is begun.

At St. Louis, the Mill Creek sewer is a notable piece of concrete construction. The section is in general a horseshoe standing on a rather flat invert. Externally, the side walls are vertical. On the interior, however, the typical open-cut section has inclined sides, the widest part of the interior being about halfway between top and bottom. The exterior sides also incline in the same direction when the rock extends above the springing line. The material is, in general, reinforced monolithic concrete. This sewer is a big one, a typical section being 10½ x 16½ ft.

A part of the sewer is in tunnel, nearly the whole of this section having vertical side walls and circular arch. The concrete here is specified to be such that the fine aggregate has one-half the volume of the coarse aggregate. To every 4½ cu. ft. of coarse aggregate, 94 pounds of cement are required.
A good deal of concrete placed at St. Louis, especially in the tunnel portion, was put in position by compressed air. The materials were dropped down thru vertical holes connecting the excavation with the surface. They were received in a hopper which stood over the mixer. The mixing apparatus consisted of a single chamber tapering underneath to about the size of the transmission pipe. At the top, this mixer had a door opening downward—that is, inward. All the materials, including water, were put in thru this door, whereupon it was closed. The interior of the mixing chamber was not provided with paddles or other mechanical devices for mixing. In fact, the mixing of the materials was accomplished by manipulating two jets of compressed air which discharged when desired into the chamber. One jet was located at the top, the other at the bottom. The lower jet was directed horizontally and was located at the elbow of the discharge tube. Part, perhaps a considerable part, of the mixing was probably accomplished in the transmission pipe immediately after discharge from the mixing chamber. After the charge was jostled by the jets, it was shot off thru the transmission piping.

The pipe line for this system may be added to at will until it is 500 or 1,000 ft. long. In the present case, it seemed convenient or desirable to use about this length, the concrete being carried along the tunnel in one direction up to the maximum length of the pipe line and then in the other direction up to the maximum length. In this way about 1,900 ft. of tunnel could be dealt with from one position of the mixer. Turns could be made readily, provided only that they were not too sharp and that the interior surface was normally smooth. The turns might lie in any plane—horizontal, vertical or oblique. The size of the transmission line used at St. Louis was, if I am not mistaken, 8 in. in diameter. A somewhat smaller size may be used, but the maximum size of coarse aggregate then permitted is reduced. In transmitting it is important not to let the pipe get full of concrete anywhere. An experienced man, it is understood, has no real trouble. The air pressure during mixing may be used in one or the other jet up to 50 pounds or even more. In actual transmission, the pressure may be cut in two after the initial dislodgement is effected. The concrete often or generally travels at the rate of 50 ft. per second in this system, so that tamping is unnecessary. It is especially suitable for placing concrete overhead, as gravitation is overcome by the drive of the air. It is not necessary that the concrete be especially wet. Naturally, one will select pipe having a smooth interior and which may readily be connected up. Lap-welded, merchant steel pipe with flanges welded on would appear to be nearly ideal. A pipe-line system such as this has a strong appeal in connection with sewer work, especially where the sewer is a small bore tunnel. The pipe affords a very compact means of transporting the concrete. It is easily lengthened and may be used again and again.

There is another system of placing concrete which is coming into notice and which has its strong points in sewer construction. This is a system which uses a special mixer and atomizer and transmits, like the compressed-air system, thru a pipe line, but uses superheated steam as the driving power. It has been used on tunnel work in connection with two old steel-lined water conduits for whose maintenance the Delaware, Lackawanna & Western R. R. is responsible.

The Public Service Commission of the First District, New York State, exercises in New York City, amongst other duties, a supervision of certain sewer construction. Four of the accompanying photographs show examples of concrete construc- tion carried out under their care.