A Practical Application of the Imperfect Ditch Method of Construction

M. G. Spangler, *Research Professor of Civil Engineering, Iowa State College, Ames*

This paper gives a brief discussion of the principles on which Marston's imperfect ditch method is based and a description of the construction plan carried out in a successful attempt to minimize the load produced by a high additional fill placed above a sewer in a regrading of a large railroad freight yard at Atlanta, Ga.

The concrete pipe sewer is now carrying the additional height of fill with no signs of distress or other evidence of load damage.

• IN 1937 the city of Atlanta, Georgia, constructed a 48-in. reinforced concrete pipe interceptor sewer in the valley of Proctor Creek in the northwest section of the city. Between Perry Boulevard and the main line of the Southern Railway, a distance of about 1,400 ft, the sewer was located on right-of-way obtained by an easement across land owned by the railroad. The city retained ownership of the sewer and responsibility for its maintenance and upkeep. The height of fill above the top of the pipe ranged from about 17 to 35 ft along this section of the sewer.

In 1955 the railroad announced its intention of enlarging its freight yard by constructing a fill in the area traversed by the sewer. The grade of the new fill was established at an elevation 95.5 ft above the top of the sewer, which increased the height of fill over the pipe by 60 to 78 ft. The dead weight of new fill to be added would impose a load at the original ground surface of approximately 17 to 22 tons per lineal foot of pipe. It was believed that if a substantial portion of this added fill load were transmitted to the existing sewer, the pipe would suffer considerable structural damage.

Several alternative proposals for meeting this situation were investigated by the Sewer Division of the city's Construction Department. One of these alternatives was to construct a new sewer of pipe or monolithic construction having sufficient strength to carry the total load imposed by a 95-ft fill. Another was to construct a reinforced concrete relieving platform or protective slab above the present sewer. The estimated cost of each of these alternatives was about $150,000.

The plan adopted was to adapt the principles of Marston's imperfect ditch method of construction, by means of which a large proportion of the weight of the added fill was transmitted by arch action to the columns of soil adjacent to the pipe, thus holding the total load on the pipe to an amount which it was estimated the pipe was capable of carrying. This plan was carried out at a cost to the city of $18,000 plus an additional cost to the railway company which is estimated not to exceed about $4,000. In addition to the monetary saving, there was considerable saving in time, inasmuch as the adopted plan could be carried out much quicker than any of the alternatives considered.

The project was completed in the fall of 1956. In several detailed inspections of the sewer during construction of the fill and after its completion on October 27, 1956, the pipe was found to be in good condition, unharmed by the greatly increased height of fill above it. A final inspection was made early in May 1957 with similar results. (Visual inspection on March 1, 1958, showed the pipe to be in good condition without visible cracks or other evidence of structural damage.)

The imperfect ditch method of construction was invented in about 1919 by Marston (*3*) in connection with his broad studies of loads on underground conduits. His earliest work in this field dealt with ditch conduits (see Fig. 1) such as sewers and drains installed in relatively narrow ditches and then covered with backfill up to the natural ground surface. In this type of installation he showed, both analytically and experimentally, that a large proportion of the weight of the backfill is carried by shearing forces which act upward along the backfill at the contact with the sides of the trench. The load which the conduit is called upon to carry is equal to the weight of the backfill prism minus these upward shearing forces. The upward direction of the shearing forces results from the fact that the backfill has a tendency to settle downward in relation to the undisturbed and relatively inert sides of the trench.

Later he studied the load situation with respect to projecting conduits, such as culverts under embankments. These are conduits installed at or near the natural ground surface and then covered with an earth fill. If the top of the conduit projects some distance above the adjacent natural ground surface, the installation is described as a positive pro-

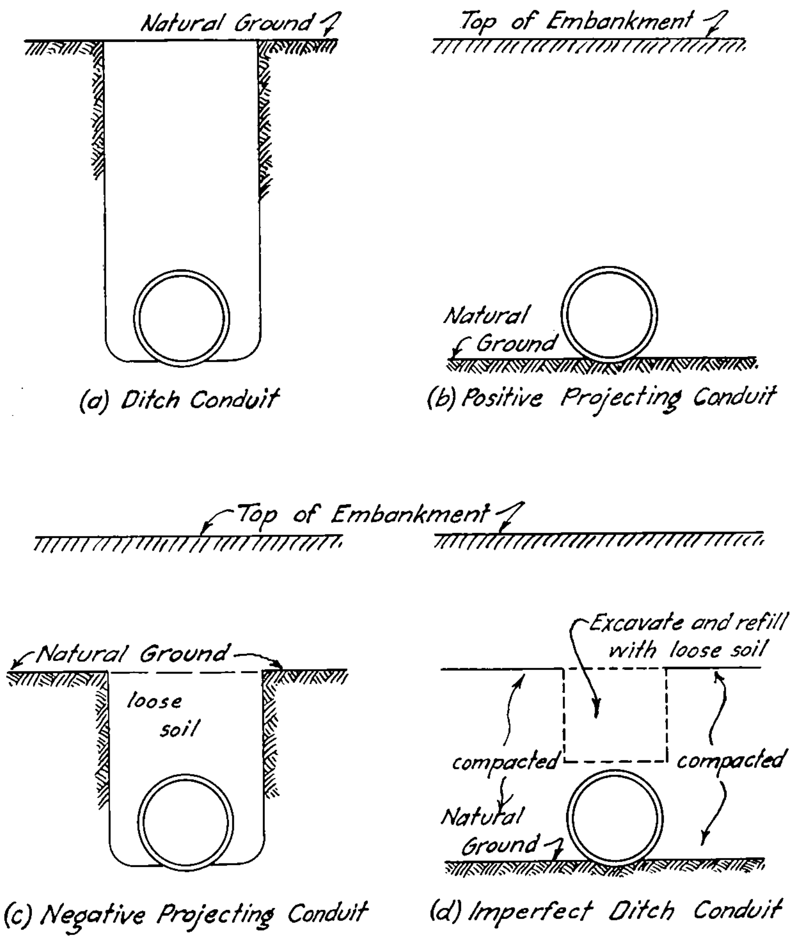

Figure 1. Types of conduit installations.

jecting conduit. Under these conditions the prisms of soil at the sides of the structure have a tendency to settle more than the prism directly above it. This differential movement between adjacent soil prisms generates shearing forces which are directed downward along the sides of the prism of soil over the conduit, and the structure is called upon to carry the weight of the soil above it plus the amount of these shearing forces. It is possible that the load on a positive projecting conduit may be very much greater than the weight of the soil above it. In some of Marston's (*5*) early experiments the actual measured loads on rigid conduits in this type of installation were 90 to 95 percent greater than the weight of the soil directly above the structure.

The imperfect ditch method of construction was devised to combat this unfavorable load situation and thus make it possible to construct a higher fill over a conduit of a given strength. In this method of construction, the conduit is installed as a positive projecting conduit. Then the earth fill is thoroughly compacted at the sides and up to some elevation above the top of the pipe. Next a trench having a width equal to that of the pipe is excavated directly over and down to the top of the structure. Then this trench is refilled with loose, highly compressible soil and the embankment construction continued in a normal manner.

The objective of this method of construction is to insure that the prism of soil directly above the conduit will settle more than the adjacent masses of soil. This brings about the development of shearing forces which are directed upward. These shearing forces help to support the weight of the soil prism directly over the structure and the load on the pipe is thereby greatly reduced. The deeper the trench which is excavated and refilled and the greater the compressibility of the refilling material, the greater will be the reduction in load on the conduit. Marston suggested that layers of straw, hay, or cornstalks might be incorporated in the refilled trench to insure a high degree of compressibility of the backfilling material.

Some years later the author (*6*) developed a theory of loads on imperfect ditch conduits and derived formulas for estimating loads for this type of construction. Schlick (*4*) presented the results of some experimental studies, which demonstrated the effectiveness of this procedure in reducing loads. The method has been used in a number of cases where high earth fills have been constructed over culverts (*7, 2*). The principle of the method has been employed by the California Highway Department for many years with conspicuous success. They have many examples of pipe culverts under high fills which have been constructed according to their "Method B" (*1*) and which are supporting these high fills successfully.

One objection to the use of this method of construction which is sometimes voiced by engineers who have not had experience with it, is the fear that a sag will develop in the roadway surface caused by the fact that the soil prism directly above the conduit is deliberately made more compressible than the adjacent prisms. This fear is groundless because (a) the method is economically justified only in the case of relatively high fills and (b) for fills of only moderate height, a plane of equal settlement develops at some elevation between the top of the conduit and the top of the fill. The plane of equal settlement is defined as a horizontal plane in the embankment at and above which the settlement of the soil in the interior and exterior prisms is the same. Therefore, when the fill height is sufficient to justify use of the imperfect ditch method of construction, it is virtually certain that the finished grade of the embankment will be above the plane of equal settlement and a sag will not develop in the roadway surface. In connection with this project the railroad engineers report that there has been no differential settlement of the embankment surface during the first 17 months since its completion.

Although the imperfect ditch method

was originally invented for the purpose of minimizing the load on culverts under new embankment construction, it was believed that the same general principle could be employed to protect the Proctor Creek sewer from excessive load due to the additional height of fill which was proposed to be placed above it. The plan adopted for this project consisted of three major parts.

First, the city excavated a 4.75-ft wide trench directly over the sewer. This trench, the same width as the outside diameter of the pipe, was excavated to a

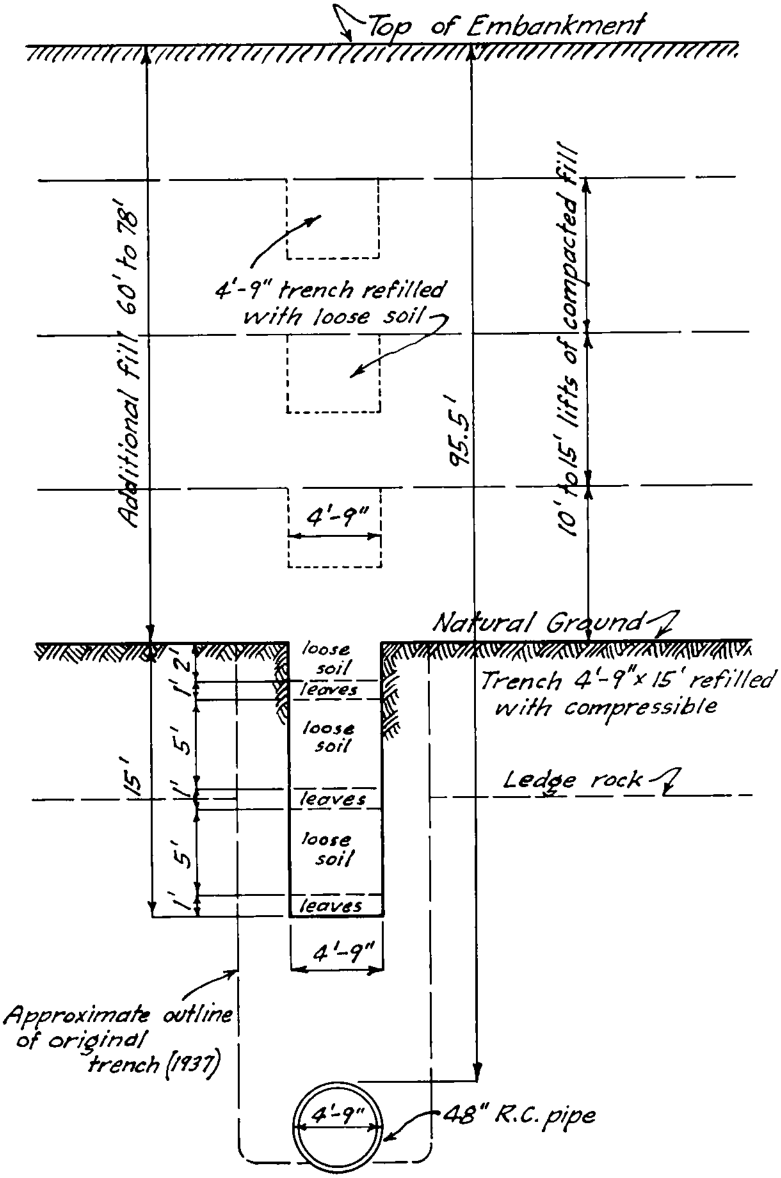

Figure 2. Typical cross-section of imperfect ditch method of constructing fill over Proctor Creek sewer, Atlanta, Ga.

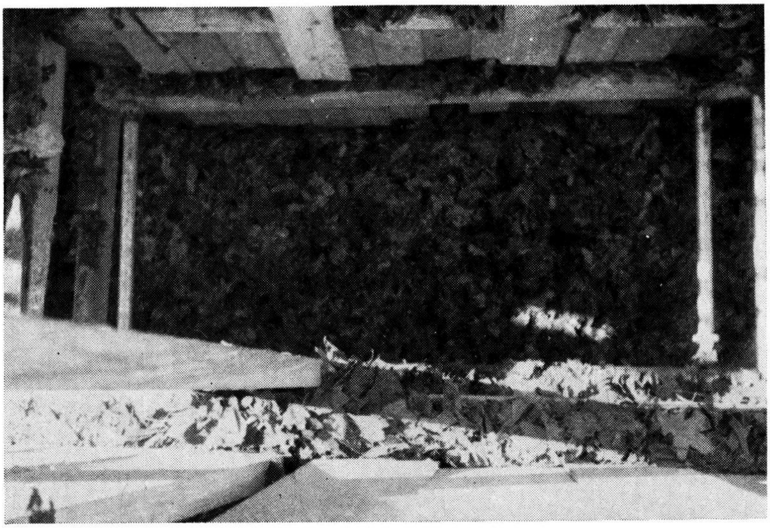

Figure 3. Bottom layer of leaves at Sta. 8 + 00.

depth of 15 ft below natural ground. The sides of the trench were sheathed and held accurately to the design width and to vertical alignment. After excavation, the trench was refilled with loose soil in which three 1-ft layers of tree leaves and pine straw were incorporated at approximately 5-ft intervals as shown in Figure 2 and the photographs in Figures 3, 4 and 5. The leaves were obtained from the Sanitary Department of the city. Later, toward the end of the project, a quantity of surplus Christmas trees was substituted for the leaves. The wood sheathing was pulled after completion of the trench backfill.

The second and third parts of the plan were executed by the Southern Railway Company in cooperation with the city. The second part consisted of placing and

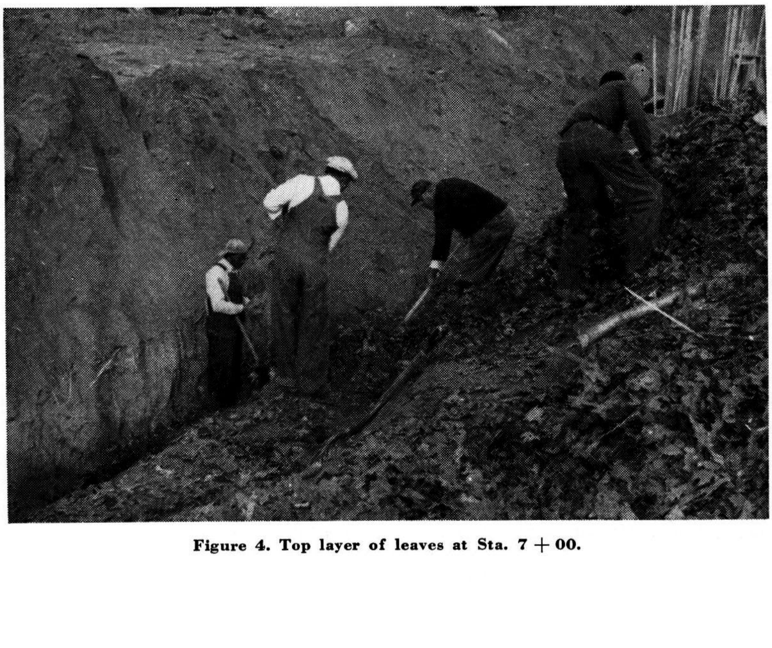

Figure 4. Top layer of leaves at Sta. 7 + 00.

Figure 5. Hand backfilling loose soil over top layer of leaves at Sta. 3 + 00.

compacting lifts of the fill in a normal manner. After a lift of about 10 to 15 ft was completed, a trench 4.75 ft wide and centered directly over the sewer was excavated in the compacted soil. The depth of the trench was about one-half the depth of the lift in which it was excavated. Then the trench was refilled with loose, uncompacted soil. This procedure was repeated up to, but not including, the last lift below the grade of the embankment.

A substantial part of the fill in this area consisted of rock from nearby solid rock excavation. As the third part of the plan, the railway company agreed to place the fill selectively in such a manner that no rock fill would be placed nearer than 75 ft to the line of the sewer.

It was estimated that the final load on the pipe after construction of the new fill would be in the neighborhood of 12,800 lb per lin ft. A search of the records of the city failed to reveal a report on the test strength of the pipes used to construct the sewer in 1937. However, the Atlanta Concrete Pipe Corporation, who furnished the pipe, supplied the information that a number of strength tests made at about the same time on their ASTM C-76-37, Table 1, pipe, the class of pipe used in the original construction, showed a minimum 3-edge bearing strength of 7,000 lb per lin ft, at 0.01-in. crack. Assuming the pipe used to construct the sewer was of this same quality, it would have to have a load factor of 1.83 as installed in order not to develop cracks greater than 0.01 in. in width.

Conversations with the resident engineer for the original construction in 1937 indicated that the pipe was installed on the equivalent of about a Class C bedding. The load factor for Class C bedding, with no allowance for lateral pressure on the pipe, is 1.5. Therefore it would be necessary to rely on side pressure to supply 0.33 of the required load factor of 1.83. Further discussions with this same individual, plus the fact that the soil at the sides of the pipe had probably consolidated to a considerable extent in the 18 years it had been in place, led to the conclusion that it would be safe to depend on side pressure support to the extent that it was needed.

This project provides an interesting and valuable demonstration of the benefit, in terms of reduction in load on an underground conduit, which may accrue from the imperfect ditch method of construction. Although, as previously noted, Marston suggested nearly 40 years prior that straw, hay or cornstalks might be used to augment the compressibility of the soil backfill in an imperfect trench, this is the first time within the author's knowledge that similar material actually has been used.

ACKNOWLEDGMENTS

The work for the city of Atlanta was carried out under the direction of Clarke Donaldson, Chief of Construction, and M. B. Nixon, Engineer of Sewers. E. H. Cook had charge of the work for the Southern Railway. The author served as consultant on the project.

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