A Practical Method for Constructing Rigid Conduits Under High Fills

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This paper gives a brief account of the design and construction of reinforced concrete pipe culverts in Humboldt County, Calif. These culverts were constructed as convential positive projecting conduits, but with a layer of baled straw placed directly on the pipe to create a condition wherein the central prism of soil above the conduit would settle more than the soil adjacent, thereby insuring the development of upward shearing forces; that is, an arching action, which greatly reduces the load on the structure. The resulting action is comparable with that obtained for negative projecting conduits (California Method B) or for imperfect ditch conduits.

Favorable results were obtained by this straw method of construction in the case of two 54-in. and one 66-in. concrete pipe culverts under fills 38 to 65 ft in height. Performance of the pipes was measured by observing the distortion of these pipes compared with the distortion of similar pipes installed conventionally. Distortion is defined as the difference between the horizontal and vertical diameters of the pipe, expressed as a percentage of the theoretical pipe diameter.

The performance of the culverts in which the baled straw method was used was much better than those in which it was not used.

• THIS PAPER is a brief account of the design and construction of reinforced concrete pipe culverts in Humboldt County, Calif. The culverts were constructed as conventional positive projecting conduits with a layer of baled straw placed directly on the pipe to obtain the loading advantages of negative projecting conduits.

The first test pipe was placed in July 1958 and is in excellent condition. This pipe and two subsequent ones have been field-checked along with three other conventional pipes on similar foundations. Figure 1 shows a comparison by distortion, which was the only practical method available without special funds for pressure plates.

In recent years there have been a number of reinforced concrete pipes in this area that have deflected and cracked seriously. It is not the purpose of this paper to discuss these installations and attempt to find factors that contributed to the failure. In general, these pipes have been placed on firmer foundations than the adjacent native soils and the foundation has usually been improved for a width of one diameter on each side of the pipe. The pipe had been produced by an established company and sample tested. Construction has been performed both by California method A (positive projecting), wherein placement consists of placing embankment to 30 in. or ⅓ diameter,

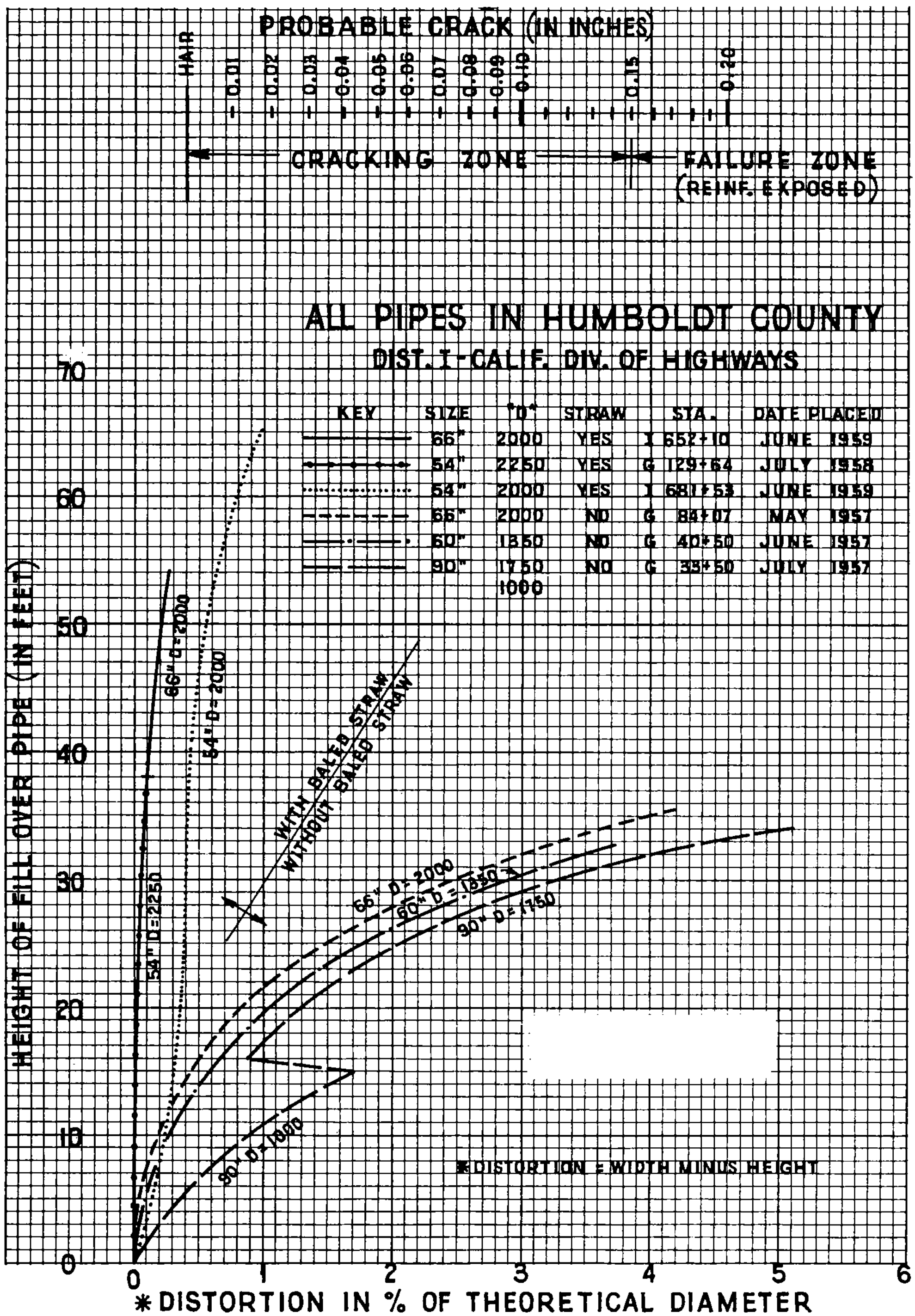

Figure 1. Report on in-place reinforced concrete pipes.

whichever is greater, above flow line, excavating a trench, placing the pipe, and backfilling with granular material; and by Method B (negative projecting with loose earth cover only), which calls for pipe placement in an excavated trench 2 diameters deep with vertical sides and with backfill compacted to the top of the pipe and remainder placed in the loosest possible condition. In all cases the cracking occurred immediately after the fill was placed and has not reappeared noticeably after repairs were made.

Only one of the cracked pipes was placed by Method B (negative projecting with loose earth backfill in a trench for 1 diameter above the pipe). The failure is generally attributed to a misunderstanding of the method of denoting the top of the pipe during placement. Most engineers seem to accept the idea that Method B placement does reduce the load on culverts under high fills. The only factors limiting its general acceptance are "practical" in nature:

1. Excavation quantities are about 3 to 4 times greater;
2. Expensive shoring is often required to preserve vertical slopes and protect workmen;
3. Modern fast-moving grading operations are often delayed by a relatively slow Method B installation;
4. An inspection (or enforcement) problem arises if the trench sides cave in—it is virtually impossible to restore material to a vertical slope; and
5. A trench filled with loose earth is difficult to maintain in that condition with heavy earth-movers and water trucks crossing it constantly.

To provide the benefits of Method B and eliminate its undesirable characteristics, the use of baled straw placed directly on a pipe that has been installed by the conventional Method A was proposed. Figure 2 showing this type of installation was distributed to designers in District 1 on November 13, 1957.

The theory of this design is summarized as follows:

1. In baled form, straw is easy to handle and resilient enough to prevent compaction of earth immediately above.
2. The sides of baled straw are vertical and provide a form to support the adjacent fill laterally during compaction. This eliminates the necessity of constructing the fill above the pipe, excavating, and backfilling with loose material.
3. Baled straw is compressible under load and will allow for settlement on both sides of the culvert without adding to the load directly on the culvert. Presuming Marston's theory to be correct, the baled straw will reduce the initial static load on the culvert to about one-third of the normal load imposed by the weight of the fill directly over the culvert.
4. Straw is organic and will therefore rot with the passing of time to produce a void over the pipe.

TEST INSTALLATIONS

The first test pipe was placed July 18, 1958, at Station G 129+64 in Humboldt County, Calif. (Fig. 3) on US 101, about 16 mi south of Eureka. It is a 54-in (2250 *D*-Load*) by 280-ft R.C.P. under a 40-ft fill. The pipe has been checked on several occasions, with a recorded inspection on May 13, 1959. This fill (40 ft to finished grade) is at the maximum allowable under current design standards for this pipe if Type A backfill is used. As reported May 26, 1959, no cracking or distress of any kind could be found in the pipe.

The second and third test installations were placed in June 1959. They

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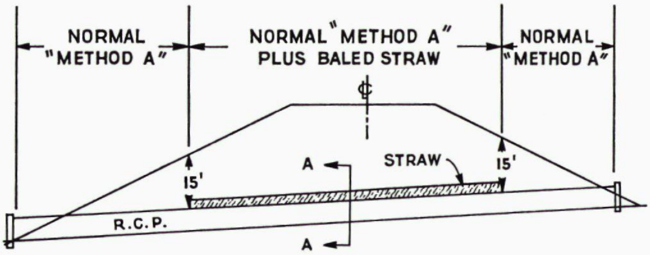
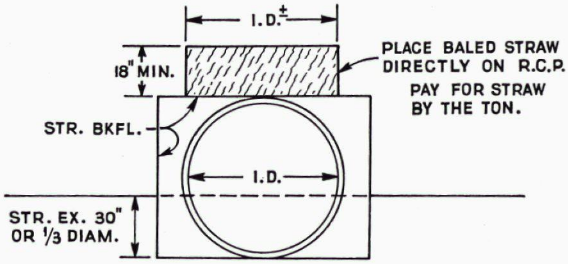
* Actual test load (in pounds per linear foot of pipe per foot of inside diameter) under the 3-edge bearing method which produces a 0.01-in. crack throughout a length of 1 ft.



TYPICAL CROSS-SECTION



SECTION A-A

Figure 2. Proposed baled straw installation.

Figure 3. First known installation (July 1958) of reinforced concrete pipe with baled straw protection. Baled straw being placed directly on top of pipe after conventional granular backfill completed.

were a 54-in. (2000 *D*-Load) by 344-ft R.C.P. at Station I 681+53 on US 101 about 20 mi north of Eureka under 65 ft of fill, and a 66-in. (2000 *D*-Load) by 299-ft R.C.P. at Station I 652+10 under 54 ft of fill. The installations are under fills that exceed design limitations for Method A by 30 ft and 20 ft, respectively.

After discussing the actual construction details with the resident engineers, the following observations were made:

1. The 54-in. R.C.P. at Station G 129+64 was placed carefully to insure compaction of the fill on both sides of the straw. A sheepsfoot

roller was operated parallel to the pipe on both sides until the fill was about 2 ft above the straw (Fig. 4).

2. Although none of the pipes with straw cover shows any real signs of distress, the 54-in. R.C.P. at Station I 681+53 does indicate that an unequal foundation (yielding with rock ridges crossing the pipe transversely) does have a tendency to cause some light cracking in spite of the straw backfill. The two rock ridges encountered in the foundation at Station 681+53 were located in the 20- to 30-ft fill range and caused the distortion curve for the pipe to make an erratic bend, even though the rock was excavated to a depth of 4 ft below the pipe.

The 66-in. R.C.P. at Station 652+10 passed very close to a rock ridge at joints 18 and 19. (The pipe was curved to miss the rock.) The only significant cracks in the pipe occurred at this location on the side opposite the rock. A case of this sort demonstrates the effect of variable backfill conditions.

CONSTRUCTION DETAILS

1. Bales should be turned on edge or sides to avoid splitting for a particular width. The nearest dimension ±6-in. of the inside diameter should be satisfactory.

2. The binders on the bales, should be cut when the embankment is even with the top of the bales, but it does not seem to be of great importance if forgotten at the crucial moment.

3. The straw should never be placed to the extremities of the fill. This would permit water to pipe through above the culvert.

4. Compaction adjacent to the straw is important. Ramping up and over the straw for hauling equipment should be allowed only at the ends. When the fill height has reached the top of the straw, the culvert location should be marked with lath and compactive effort held to a minimum over the straw for an additional height of ½ in. in diameter. This means that rollers should continue to turn parallel to the culvert and work the fill in two sections. Earth-movers should

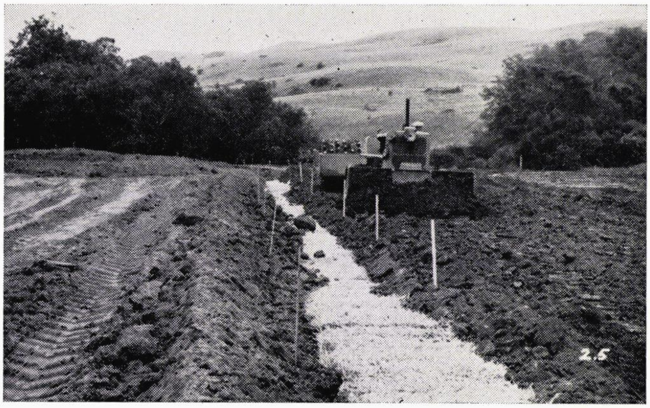


Figure 4. Embankment being placed adjacent to straw. This method was used until fill was about 2 ft above straw. Earth-moving equipment crossing pipe only at ends and dumping parallel to pipe; inconvenience to contractor slight. No problems encountered in this first installation.

also be encouraged to make their unloading pass adjacent and parallel to the culvert.

5. An economical means of checking the loading conditions on a pipe culvert is to measure the horizontal and vertical axis of each joint (or at intervals of 8 ft± for C.M.P.) with no load, full static load, and again about two years after construction.

6. The construction details should be covered in the special provisions for the project as the method will probably be unfamiliar to both the contractor and engineers. If possible, the designer should visit the project just before construction of the culverts to make certain that the basic principles are understood.

Figure 5. Trenching and straw placement above existing 36-in. R.C.P. (D-load=1,750 lb) to be covered with 62-ft fill to convert existing expressway to full freeway. Trench cave-in will do no serious harm, even though it is desirable to maintain vertical sides. Excavation being performed in unsuitable material from previous construction project.

7. The baled straw method of construction works very well where a culvert is already in place (Fig. 5) and the fill is to be increased beyond the allowable limit. A trench is excavated to within 3 ft± of the pipe, straw is placed immediately (so trench cave-ins do not have to be re-excavated) and the trench filled with loose earth. Only one installation of this type has been completed. It was placed in September 1960 and shows no signs of failure, even though the pipe was located in a disposal area for unsuitable material on a previous project and the fill exceeds the "allowable" under Method A by some 35-ft.

CONCLUSIONS

1. It is now reasonably conclusive that a layer of baled straw does produce the desired load reduction on the pipe. The amount of this reduction will vary with foundation conditions and degree of compaction of the material immediately adjacent to the straw. It would seem that fills of about three times the height allowable for normal Method A installation could be supported without serious damage to the pipe under average conditions (*1*). Under favorable conditions (uniform foundation under pipe and adjacent area, plus proper design and installation), it is not unreasonable to assume that fills of unlimited height can be safely constructed over rigid R.C.P. with straw cover.

2. The depth of straw required for a particular installation should be based on size of culvert, relative differential in foundation under and adjacent to the pipe, the height of fill to be supported, and the type of material used to construct the fill. As much as 5 ft of baled straw is being proposed on a 14-ft reinforced concrete arch under 180 ft of fill in Mendocino County at Mallo Pass Creek. The use of straw on an arch

was not previously considered to be of value but a recent 14-ft arch installation under 80 ft of fill at Luffenholtz Creek in Humboldt County is settling and separating at the lower portions of the expansion joints (pivoting about the crown). It is hoped that the use of baled straw will prevent this type of settlement.

3. Experiments are being conducted with C.M.P. under fills in excess of that normally permitted for a particular gage and bolt spacing. If successful, this will allow construction of fills that were previously avoided because of the cost of providing a suitable drainage facility. Today's higher traffic volumes and speeds require better alignment, which in turn means heavier grading. Mountainous terrain often requires maintenance of all cut sections in side-hill conditions on both sides of a steep canyon that runs perpendicular to the desired direction of travel. Advantages in user benefits, earthwork balance, and future maintenance are apparent if the canyon can be crossed without swinging upstream into a switch-back situation just to keep the fill to a particular limiting height.

REFERENCE

1. SPANGLER, M. G., and SCHLICK, W. J., Iowa State College Bull., Eng. Rept. 14 (1952).

DISCUSSION

JOHN G. HENDRICKSON, JR., *Director of Engineering-Research, American Concrete Pipe Association.*—The author is to be complimented for having found an easy, practical, and an apparently effective method for reducing the load on culverts due to high fills.

The California Method B procedure has probably been more frequently used than any other method in obtaining a negative projecting culvert installation. That it is correct in theory and in practice also if properly carried out appears to be proved. Many alternate methods have been used and are generally classified as imperfect trench methods of construction. The difference is that in the imperfect trench the fill is built up over the pipe. A trench is excavated above the pipe and backfilled with compressible material.

Each procedure has certain advantages and disadvantages. From the contractor's point of view Method B procedure is often preferred. This allows the contractor to build the lower portion of the fill up to 1 diameter over the pipe unhampered by the presence of the pipe. This often may give him greater freedom in the movement of his equipment. However, in an area subject to sudden and severe storms, there is some risk of a washout unless some alternate drainage can be provided. The use of baled straw with the Method A construction decreases this risk.

Placing the pipe in a trench with vertical sides results in a load that is proportional to the trench width. The standard imperfect trench or the use of the baled straw results in a load proportional to the outside pipe diameter. Other things being equal, this load will be somewhat less.

The writer has always been somewhat skeptical of whether the backfilling around the pipe in a trench is generally as effectively carried out as when the fill is built up around the pipe. Consequently, lateral pressure may not be fully developed for the trench installation. The question then arises as to whether some of the problems with Method B construction have occurred out of a failure to develop lateral pressure on the pipe fully. Certainly if this has been a fault of Method B construction, the use of Method A with baled straw should be less susceptible.

The use of baled straw over the pipe effectively provides a compressible prism and avoids the need for the trench used in the standard imperfect trench procedure. The construction of this trench is not a major problem provided the contractor uses the proper equipment. A backhoe seems to work best in maintaining a straight trench with vertical sides, although a dragline also seems to work well. A trench 5 ft wide and 5 ft deep and about 250 ft long was completely excavated and backfilled with loose topsoil in about 5 hr on an installation in Illinois.

The thought of placing compressible material which may eventually decay in the middle of a highway fill has been accepted reluctantly by some highway engineers. Yet the use of leaves, straw, etc., is not entirely new. In his paper "A Practical Application of the Imperfect Ditch Method of Construction," M. G. Spangler describes the use of leaves, straw, and a quantity of surplus Christmas trees together with loose soil. This project was completed in the fall of 1956 and no settlements on the top of the embankment have been observed to date.

A portion of Interstate 74 in Vermilion County, Ill., in the Kickapoo Park Area crosses a ravine with a fill 37.5 ft above the top of a 48-in. reinforced concrete culvert. An imperfect trench method of construction was chosen. The trench excavated over the pipe was filled to about one-third of its depth with loose straw which was then covered with loose soil. The fill was brought up to grade, being completed in November 1959. Periodic examinations of the site since then have found no signs of distress in the pipe. There has been no settlement in the fill and none is anticipated.

The relocation of US 69 in Cherokee County between Tyler and Jacksonville, Texas, required a number of small drainage structures under embankments exceeding the maximum allowable for standard reinforced concrete pipe culverts. The imperfect trench method of construction was used for ten pipe culvert installations on this project. The bottom of the trench excavated over the pipe was filled with sawdust to one-third of its depth. The remainder of the trench was filled with compressible soil material. This project has recently been completed and is being closely observed. To date no signs of failure or settlement have been found.

The preceding installations are examples of the use of the imperfect trench method of construction where organic material that may eventually decompose has been used. To date no adverse effects of using this material have been observed. The same results would be expected from the use of the baled straw in the California method. The utilization of the shearing strength of the soil to support part of the load over a culvert is perfectly justified and is good engineering practice. It is also proving to be an economical means of constructing high fills over standard reinforced concrete pipe. These and other advantages already discussed by Larsen make the California procedure appealing to highway engineers.