Precast Reinforced Concrete Box Culverts

Experimental Feature
Final Report

by

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INTRODUCTION

In 1977 an extensive storm drainage system was constructed along Interstate Highway 5 in northeast Salem, Oregon. Included in this project was the installation of approximately 2,400 ft of twin box culvert. Because several portions of this box culvert were placed under existing roadways which could either not be closed to traffic or only partially closed for short durations, three different methods of culvert placement were used. For the 2,000 ft of culvert which did not affect traffic, the standard poured-in-place method was used. For the segments of culvert where the poured-in-place method would have resulted in undesirable traffic interruptions, two additional methods, open trench and jacking, both using precast reinforced concrete boxes, were specified. Because these two methods of placing precast box culverts were relatively new, these portions of the project were classified as experimental features and evaluations and reporting were scheduled. This is the final report on the experimental aspects of the study.

The importance of the Market Street Interchange on Interstate Highway 5, where the culvert passes beneath the southbound on-off ramps, made it desirable to maintain unimpeded traffic during construction. Precast box sections were jacked under the ramps allowing an almost uninterrupted flow of traffic. Where the culvert crosses Market Street, a main arterial, traffic volumes dictated that only one half the roadway could be closed at a time and safety considerations dictated that construction occur only during daylight hours. Precast box sections were placed in an open trench under one half of the roadway while traffic was maintained on the other half. Complete installation required only two days, one day for each half of the roadway.

CONSTRUCTION

The poured-in-place segments of this project were double barreled culverts, with the 6 by 4 ft barrels separated by a common wall. In the precast segments of the project, each 6 by 4 ft box section, 6 by 4 ft in cross section and 8 ft in length, was cast separately and the twin culverts were placed side by side. The precast box sections had a 7-sack concrete mix with a 3 to 4 in. slump and a 3 to 5% air content. Sections were cast in steel forms equipped with vibrators and each section was steam cured at 100 F for 12 hours. Some of the manufacturer's patches were defective and softened when exposed to moisture. The manufacturer rechecked all the patches and replaced the defective ones.

Jacking Placement

The appendix contains a series of photographs showing the machinery and the construction techniques used to jack the box culverts under the Market Street Interchange on-off ramps.

The contractor selected the Akkerman 700 System Boring and Jacking Machine. The boring components of this system consisted of a 48 in. diameter rotating cutting head followed by rectangular cutter which enlarged and shaped the hole to the outside dimensions (7 ft 2 in. by 5 ft 2 in.) of the single box culvert.

A conveyor belt carried the material excavated by the circular borer and the top corners of the rectangular cutter to an electric ore car, which ran on a track to the entrance. There it was lifted out of the working pit by a crane and dumped. Material excavated by the bottom corners of the rectangular cutter had to be hand shoveled into the ore car. A hydraulic ram was fitted to the culvert sections with a rectangular yoke designed to spread the ramming energy equally along the face of the section. The ram pushed the culvert sections into the bored opening immediately following the cutters. The hydraulic system which was used to run both the circular cutter and the ram, was powered by a 440 volt diesel generator.

In order to shorten the jacking distance, the working pit was excavated in the middle of the median island separating the on and the off ramps. Using this central pit the box culvert could be jacked in each direction, reducing by half the distance that each run would be pushed. The working pit was excavated 15 ft deep with an 18 by 36 ft working area. The bottom of the pit was poured with a 12 in. concrete slab to provide a solid working base and the walls were shored with timber and steel wide-flange beams.

The box culvert sections were lowered into the pit and placed into position by a crane. Plywood rings were inserted between sections to reduce damage by cushioning the faces of the boxes. Kent Seal No. 2, a butyl rubber based flexible joint sealant, was placed around the male end to seal between sections. Because the force necessary to move a long line of boxes probably would cause excessive damage to the sections, intermediate jacking stations were necessary after every three sections. These intermediate stations consisted of 16 hydraulic cylinders, which were aligned between two sections; four cylinders on each edge. Hoses connected these intermediate stations to the main control area so that the train of boxes could be advanced in series with only three sections being jacked at a time. This procedure reduced the amount of energy that was delivered against the faces of the boxes and when combined with the plywod rings provided excellent protection from damage to the boxes during installation. Damage, limited to the lead section of each run, was easily repaired.

Four runs from the central pit, two in each direction, were necessary, to push the twin culverts under the on-off ramps. Each run was approximately 72 ft long. The two runs under the southbound on ramp were made first. The first run was made in four work days. The second run was made in a little over three work days. The first run to the north under the southbound off ramp was not so fortunate. The box hung up on something and dislodged so much material that the roadway settled and had to be patched. This run, including delays, took ten work days. The last run hit the same obstruction but was able to keep going with extra jacking stations.

After the precast sections were jacked into place a closure pour was made in the jacking pit. Access manholes were provided at this location. The entire run was then pressure grouted through holes in the precast sections, to insure that voids created by jacking were filled.

The most time consuming part of the jacking operation was the necessity to hand shovel behind the rectangular cutter. The hand shoveling was physically demanding, especially considering the cramped working conditions. The project would have proceeded significantly faster had it been possible to place a circular culvert behind a boring head which matched the culvert in size, negating the need for the enlargement and shaping by the rectangular cutter.

Open Trench Placement

Three photographs showing the open trench precast culvert placement under Market Street are included in the appendix. One half the street was excavated at a time. Because of the heavy traffic volumes, traffic control was necessary and street closure only during daylight hours was desirable. The excavation was made to 6 in. below grade and 6 in. of bedding was placed. The precast sections were lowered into place by a crane. The gasket material was placed near the leading edge of the male part of the joint, on the top and sides, and on the female end the sealer was placed on the bottom and up the fillet. This allowed the soft gasket material to roll and spread as the sections were pressed together. The sections that were not done in this manner leaked with the first rain and the contractor had to return and seal the joints from the inside with grout. After the gasket material was in place, the sections were pushed together with a backhoe. Some joints in this open trench section are noticeably wider than in the jacked sections. The backhoe was not as effective as was the jacking machine in delivering the necessary force to properly seal the joints. This probably explains the leaking and the follow-up grouting that was mentioned above.

Two features of the open trench placement, set-up and connecting inlet pipes from catch basins, required more time than anticipated and; therefore, prevented the completion of the installation during daylight hours. Due to the required use of concrete traffic barriers, the preparation for the lane closure and detour took 1 1/2 hours, and resulted in a cramped work area. Drainage from catch basins along Market Street intercepted the precast culvert at both edges of the roadway. The field cutting of holes in the precast sections and the grouting in place of the inlet pipes was very time consuming. Considerable time could have been saved if holes for the culvert inlet pipes had been blocked out when the sections were precast.

INSPECTIONS

The precast reinforced concrete culvert segments have been inspected twice, in July 1979 after two years of service and in October 1982

after five years of service. The joints both in the open trench placement segment, after the above mentioned internal grouting, and the jacked placement segment show no signs of leakage. Cracks in the ceiling of the culvert are few and insignificant in size. The precast culvert has performed excellently, equaling or exceeding the perfrmance of the poured-in-place culvert located at other segments of this project.

COST

The three bid items concerning culvert placement for the twin 6 by 4 ft concrete culvert installed on this project are summarized as follows:

Item	Dollars per linear ft
(1) Base price including boxes and installation	185
(2) Extra for placing precast box culvert under pavement	42
(3) Extra for jacking placement	444

The first item is the total cost for the poured-in-place box culvert, the nonexperimental portion of the total project. This first item is also a base price for the precast experimental portions of the project placed in open trench and by jacking. The second item adds an extra amount where the culvert passes under a roadway and pays for the repaving of the road. Although this item pertains only to the precast open trench placements, it does not actually differentiate the precast open trench from the poured-in-place placements, since if the poured-in-place method had been used under a roadway, this extra amount would also have been paid. The third item pays for the boring and jacking operations, and when added to the base price amounts to $629 per linear foot.

CONCLUSIONS AND RECOMMENDATIONS

Both the open trench and the jacking placement of precast concrete culvert were successful. A minimum of construction problems were encountered and the culverts have functioned well during five years of observation. This process is recommended when the affected roadways cannot be closed or can be only closed for short periods. The following were recommendations from the project engineer:

(1) If strength, clearance and hydraulic considerations can be met with round pipe it would greatly speed the jacking process especially if the cutter head matches the culvert size. Using box culverts, the placement of the culvert is slowed by the necessity to manually shovel the debris out from the bottom corners of the rectangular section.

(2) Where inlets connect to the precast sections in open trench placement, holes should be blocked out in the precast sections to accept the inlet pipes.

(3) Closing and sealing the joints in the open trench method requires both proper placement of the sealer and greater horizontal force than could be delivered by the Caterpillar 235 backhoe. Some method of providing more horizontal force would have eliminated the necessity to internally grout the joints.

The Oregon State Highway Division will specify the open trench placement of precast concrete culvert when short duration partial road closure is permissible and jacking placement when it is necessary to maintain traffic without any road closure.

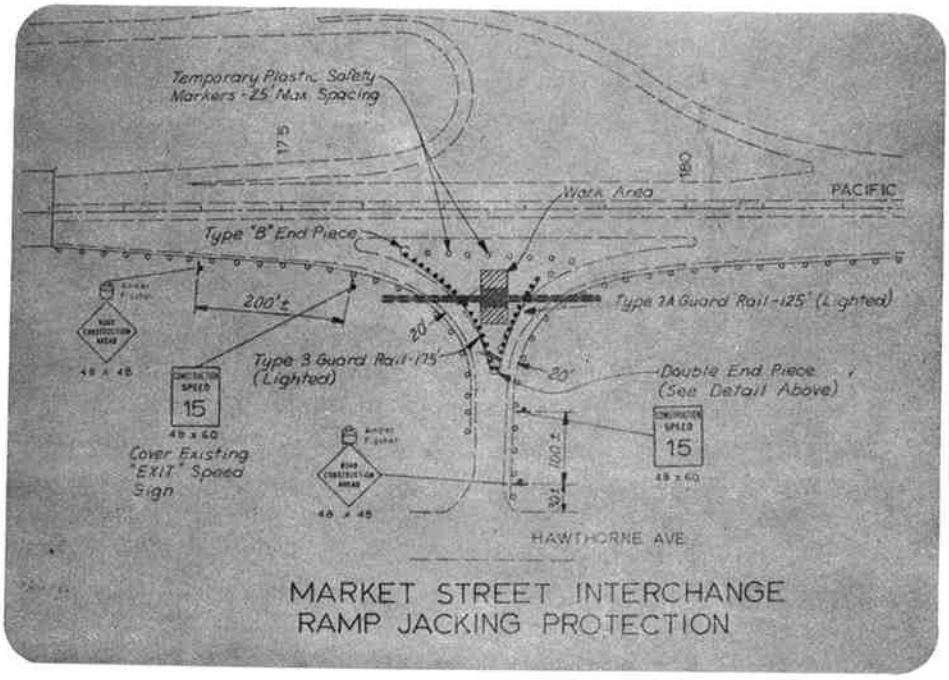

Figure 1. Location map. Market Street Interchange, Interstate Highway 5, Salem, Oregon.

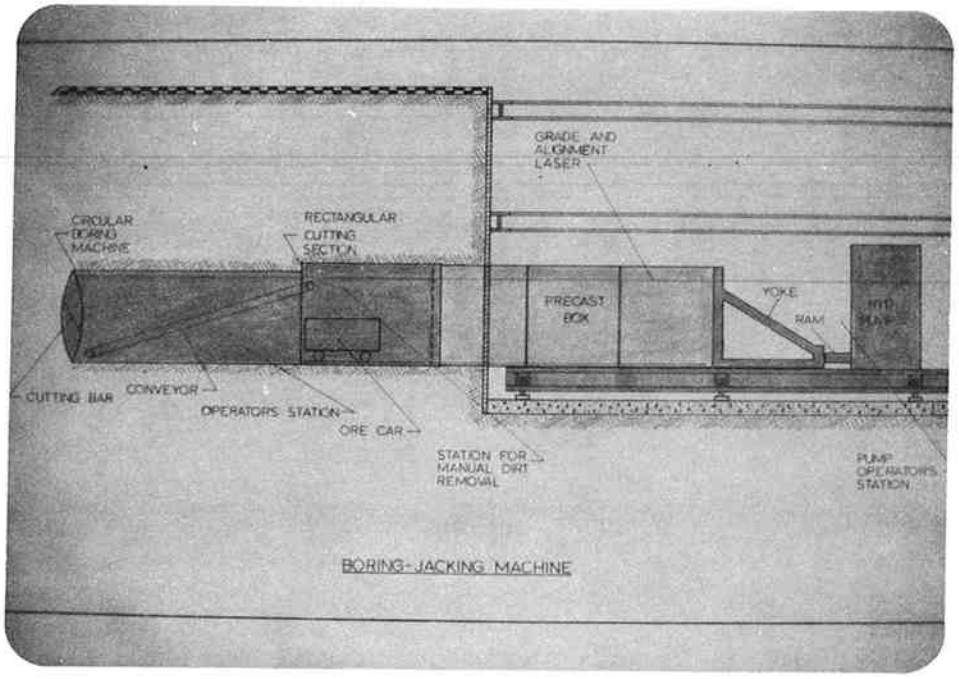

Figure 2. Components of the Akkerman 700 System boring and jacking machine.

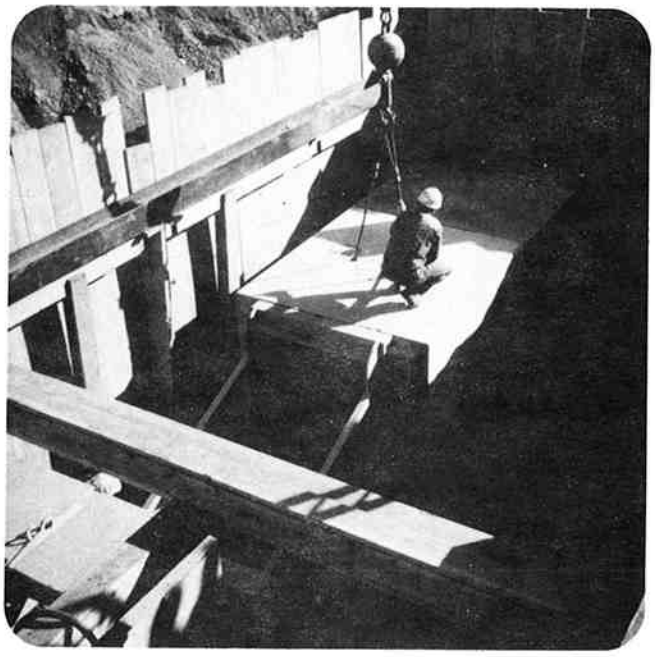

Figure 3. The first culvert section being placed between the cutters and the ram.

Figure 4. Conveyor belt loading coal car. Notice operator's position immediately behind cutter head.

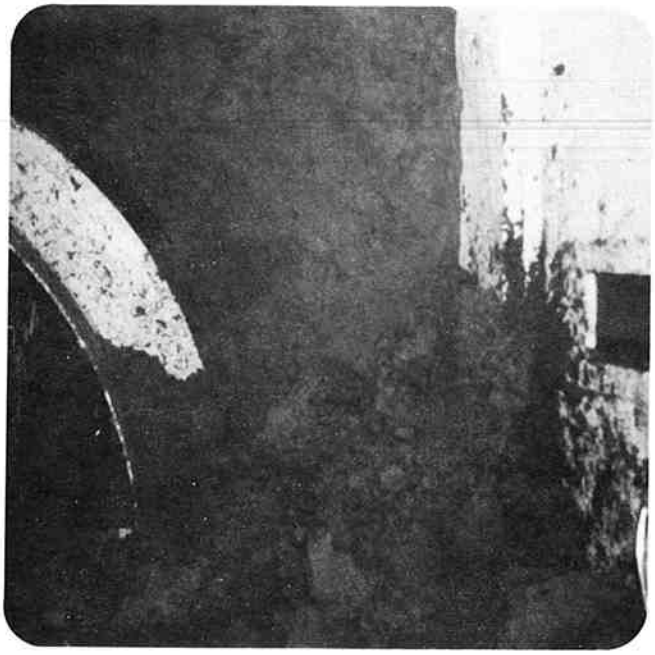

Figure 5. Rectangular cutter following the circular borer.

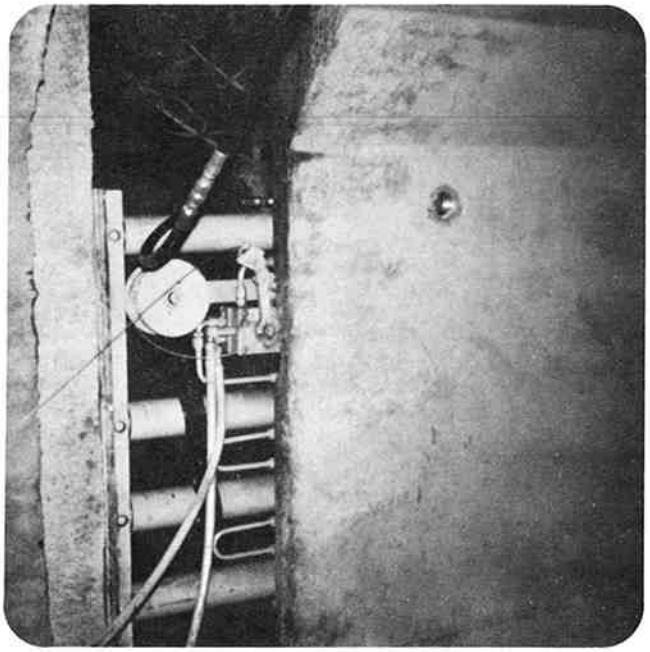

Figure 6. Intermediate jacking station placed after every third culvert section.

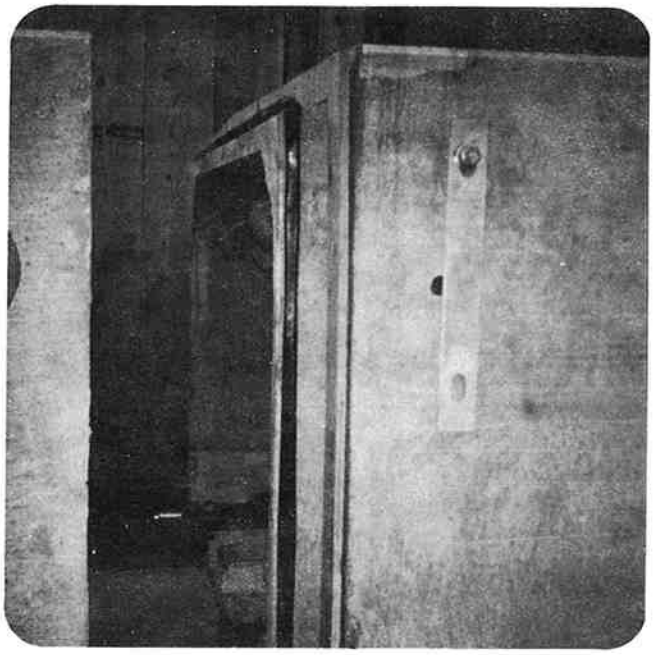

Figure 7. Sealer and plywood protection gasket.

Figure 8. Boring machine holing through.

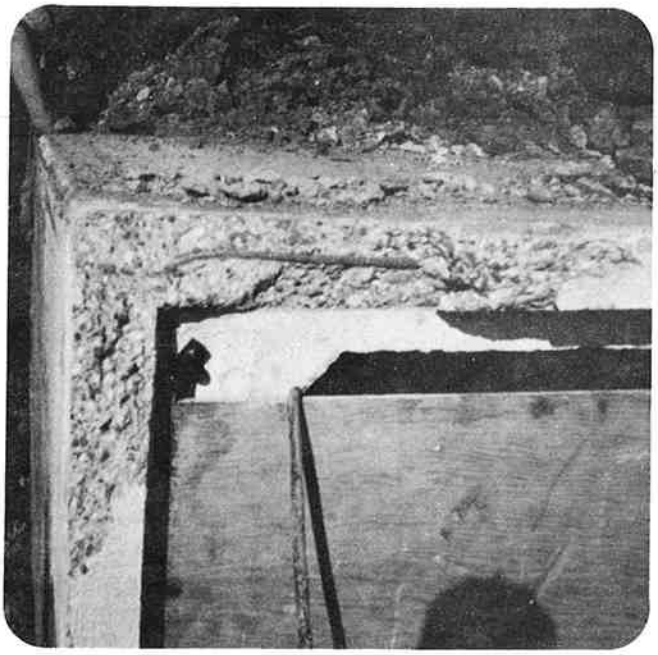

Figure 9. Typical damage to leading section.

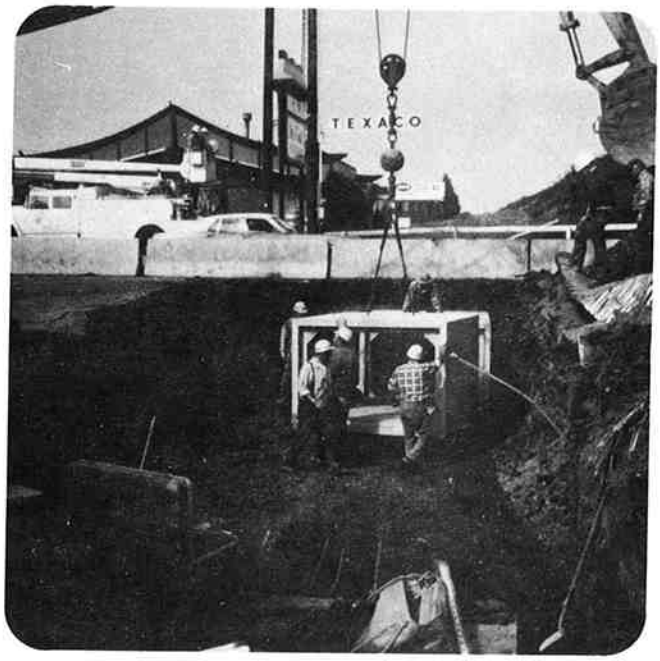

Figure 10. Crane placing precast boxes in open trench.

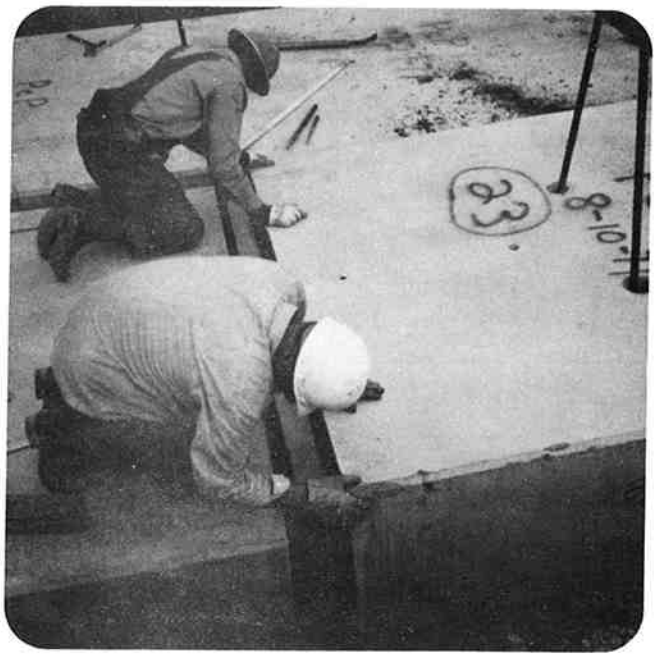

Figure 11. Placing sealer.

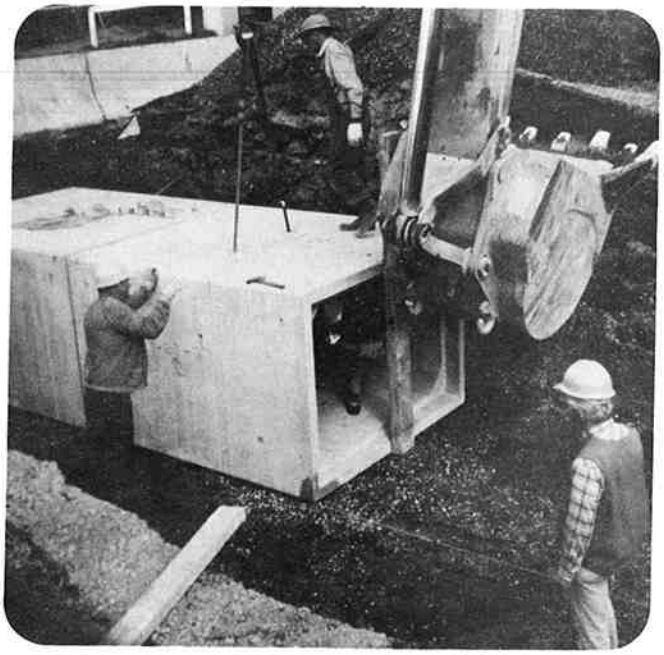

Figure 12. Sections pushed together by backhoe.