Behavior of the reconstructed Wolf Creek culvert
by Gerald Anson Willett

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Civil Engineering
Montana State University
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Abstract:
The failure of an 18.5 foot diameter structural-plate culvert under 83 feet of cover led to its reconstruction using the "imperfect trench" type of construction as well as other changes , This paper reports the findings of a research project that was initiated to study the behavior of the reconstructed culvert, The study was sponsored by the Montana State Highway Commission and the Bureau of Public Roads and was performed by the Department of Civil Engineering and Engineering Mechanics at Montana State University.

The reconstructed culvert was instrumented to study its behavior. Instrumentation consisted of: SR-4 strain gages placed on the culvert walls at approximately mid-height; Carlson Soil Stress Meters, placed on the outside walls of the culvert and in the fill; rubber pressure cells, which were commercial hot water bottles , placed in the fill; and settlement cells, which were placed in the fill oh each side of the culvert ,, Also, measurements that were taken included: levels on the culvert invert, vertical and horizontal diameters, and levels of the roadway profile.

Computer programs were developed to determine stresses and earth pressure from data obtained by periodic readings of the instruments .

Overall, the instrumentation performed satisfactorily. Results from strain gages, stress meters, and rubber pressure cells, correlated well and demonstrated that the vertical load on the culvert was much less than the weight of the overlying column of earth - a highly favorable load condition which the "imperfect trench" method of construction was expected to produce. The SR-4 strain gages, which measured bending strains in addition to circumferential compression, showed that significant residual bending stresses were induced in the plates during erection. They also monitored bending stress changes that occurred at the strain gage sites during and after the backfilling operation. The vigorous compaction of the backfill on each side of the culvert, during the early stages of backfilling, produced a bending stress pattern in the side walls that persisted throughout the embankment construction period and thereafter.

There was no measurable differential settlement of the pavement attributable to the "imperfect trench" type of construction.

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ABSTRACT

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There was no measurable differential settlement of the pavement attributable to the "imperfect trench" type of construction.

CHAPTER I

INTRODUCTION

This paper describes the behavior of an 18.5 foot diameter structural-plate culvert that was reconstructed after the failure of the original structure. Construction of the original installation began in the fall of 1963. The rock fill, which provided approximately 83 feet of cover on the culvert, was completed in the spring of 1964. It was discovered that the structure had failed in the summer of 1964, within three months after the fill was completed, but it is not known exactly when the failure began.

Solutions for repairing the structure were reviewed and the final conclusion was to remove the fill and rebuild the failed portion of the culvert. Removal of the fill began that winter. Reconstruction of the culvert was delayed until the following fall, 1965, because of higher than normal runoff and the resulting problem of stream diversion.

Extensive testing by the culvert contractor was done to determine the cause of the failure. The test results indicated that the failure may have been caused by "hydrogen embrittlement" of the zinc-coated high strength bolts. It was thought by some of the engineers involved that the culvert loading may have been larger than anticipated; therefore, the reconstruction was designed for an increased margin of safety. In addition to changing the type and size of bolts, an "imperfect trench"

type of construction was used. It was decided that the culvert should be instrumented and that a study should be made on the behavior of the reconstructed culvert.

The design and installation of instrumentation, and the study of the behavior of the reconstructed structure was performed by the Department of Civil Engineering and Engineering Mechanics at Montana State University. The study was under the sponsorship of the Montana State Highway Commission and the Bureau of Public Roads.

CHAPTER II

BACKGROUND INFORMATION ON THE WOLF CREEK CULVERT

The culvert installation is located on Little Prickley Pear Creek near the south end of Wolf Creek Canyon on Interstate Route 15, about 25 miles north of Helena, Montana. The Interstate plan-profile at the culvert site is shown in Figure 1. The design details of the original culvert are covered in a paper by Kraft and Eagle (8)[1].

The culvert was 548 feet long. Corrugated and galvanized structural steel plates, 3/8 inch thick, were used in the middle 328 feet and thinner plates were used near the ends.

Design loading on the structure was 8.2 kips per square foot from 83 feet of fill having an assumed unit weight of 105 pounds per cubic foot. The use of 3/8 inch plate and 3/4 inch high strength bolts resulted in a design seam strength of 270,000 pounds per linear foot and provided an apparent safety factor of 3.5. The high strength bolts used with the 3/8 inch plates of the original culvert were zinc-coated ASTM A490 bolts while the remaining bolts used with the thinner plates, were zinc-coated ASTM A325 bolts. Because the original structure was not instrumented, the actual load on the structure could not be determined.

The failure was due to "brittle-like" fracture of the bolts along the longitudinal seams of the lower half of the culvert. The failure

[1] Numbers in parentheses refer to references listed under Literature Cited.