DISCUSSION OF PROGRESS REPORT ON CULVERT INVESTIGATION

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Referring to the first progress report of the Culvert Investigation by Messrs Crum and Morris, it is noted that the purpose of this investigation is to conduct a fact-finding survey of small drainage structures in order to determine methods in arriving at the economic values of various types of such structures, or in other words, the objective of the investigation is to provide the engineer with the basic principles by which he may decide upon the economic structure to use under a given set of conditions

In a supplementary report which has been presented at this meeting by Mr Crum, a tentative method for rating culvert pipes in conformity to the above has been suggested, and it has been based on a field survey of 516 culverts distributed throughout fourteen states

The purpose in attempting to set up a rating scheme or equation is to determine the probable normal life of the drainage structure under various prevailing conditions Or in other words, the rating is a function of the economic life of the structure The authors are very explicit in stating that the rating system, as suggested in this supplementary report, is merely tentative, and that the main use is to encourage the collection of valuable data in the solution of the problem of economic life of drainage structures

The rating equation, as suggested, is based on the depreciation and deterioration of the barrel due to the principal destructive forces and modified by the external condition of installation

The rating equation is represented as follows

$$R = \text{Age} - B + \frac{E}{10}$$

In this equation B and E refer to barrel and external condition, respectively The age is merely a prefix and does not enter into the equation, although it appears somewhat misleading in the rating equation as presented

The two destructive forces causing tentative failures are evidenced from structural weakness and deterioration of material, and it seems the rating scheme or equation should be so designed as to take into consideration ratings obtained from all destructive forces, because it

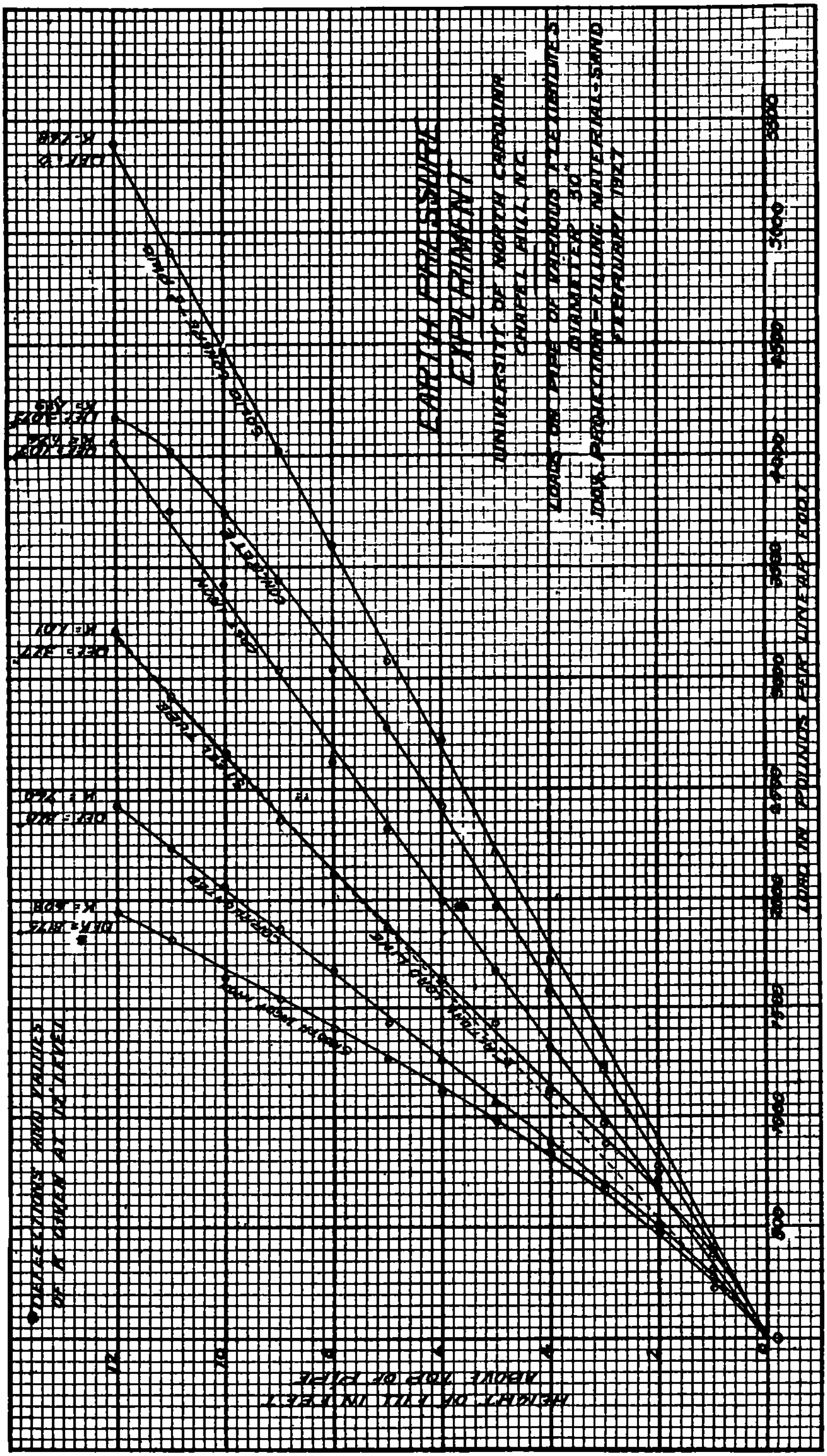
EARTH PRESSURE EXPERIMENT
UNIVERSITY OF NORTH CAROLINA
CHAPEL HILL, N.C.
LOADS ON PIPE OF VARIOUS FLEXIBILITIES
DIAMETER 30"
FEBRUARY 1927
DEFLECTIONS AND VALUES OF K GIVEN AT 12' LEVEL
LOAD IN POUNDS PER LINEAR FOOT
HEIGHT OF FILL IN FEET ABOVE TOP OF PIPE

Figure 1

is quite possible that one or a combination of destructive forces might cause tentative failure It appears from reading the supplementary report, that the authors intended that only the principal destructive force should be considered in the rating equation

It is realized that the rating schedules for barrel condition given in the tables for the various kinds of pipe are tentative only, but it would have been interesting, and would no doubt have added to the value and clarity of the paper if some actual examples had been worked out in connection with the rating equation as submitted It is doubtful whether the rating equation should be modified by a factor obtained from the external conditions of installation as suggested by the authors Under certain conditions of a very low barrel rating this factor would have a large influence on the final rating which properly would not occur in actuality

The insufficient data presented indicates that this report is only tentative and that further study is necessary It is to be hoped that the Committee will in its future study make use of the material already collected by various states

The loads from embankments are some of the principal destructive forces that occur in structurally weak drainage structures, and it is extremely important to have accurate information regarding the effect of these loads on culvert pipes At the suggestion of Mr T H McDonald and Director C M Upham, I will take the liberty of giving some results that have been obtained from a series of experiments undertaken by the University of North Carolina to obtain actual pressures on culvert pipes

These culvert pipe experiments have been under way for the past four years, and were commenced at the suggestion of Mr. Frank Page, Chairman of North Carolina Highway Commission, and Mr Chas M Upham, then Chief Engineer, and are being carried out under the staff members of the Engineering School of the University of North Carolina A progress report of the first series of experiments may be found in *Public Roads,* January, 1927, issue.

A continuation of these experiments is being carried on as a project agreement between the United States Bureau of Public Roads and the North Carolina Highway Commission, and a brief description of the results of this second series of experiments is given in this article.

Realizing that in accordance with the theory on culvert pipes, namely, that the pressures are functions of the relative deflections of pipe and earth alongside at level of top of pipe, provisions for ascertaining the pressures on pipes of various flexibilities were made in this second series of experiments

Six different kinds of pipe of varying flexibility, each having a diameter of 30 inches, and a length of 2 feet 6 inches, were used These consisted of a solid concrete plug of practically no deformation, reinforced concrete pipe, 2½ inches thick, cast iron pipe with a barrel thickness of 1 inch, smooth steel pipe five-sixteenths inch thick, corrugated pipe of No 12 gauge, and a smooth wrought iron pipe of No 12 gauge Embankments 12 feet in height have been built for each kind of pipe, and scale readings have been observed and recorded for each 1 foot interval The material used in the embankment consisted of the same kind of sand that was used in the first series of experiments In addition to obtaining data from scale readings, it was deemed desirable to obtain pressures from soil-pressure cells, and accordingly each of the four test pipes for the different set of experiments were supplied with seven pressure cells The data obtained from these experiments on pipes of different flexibilities verifies fully the theory on culvert pipes as given above (see article *Public Roads*) They have shown conclusively that the relative deflections must be taken into consideration when attempting to estimate or compute the culvert pipe pressures by any theoretical formula.

The tests that were made near Farina, Ill, under the auspices of the American Railway Engineering Association, indicated that this is true, although unit intensities of pressures were obtained in these experiments by means of soil-pressure cells

The earth pressures on culvert pipes that were determined at Ames, Iowa, under the direction of Dean Anson Marston, of Iowa State College, applied only to bodies comparable to solid cylindrical bodies practically free from deformation or deflection In order to obtain data that would compare with his experiments, we used in Chapel Hill in one set of experiments, a solid concrete cylindrical body 30 inches in diameter and 2½ feet long We naturally would not meet with such conditions in practice, but in order to make our set of experiments complete, a solid concrete plug was included in the series The value of *K*,—ratio of weight of material over pipe to earth pressure on pipe—obtained from the solid plug was 1 68 at the 12-foot level Marston obtained a maximum value of approximately 1 9 from his experiment

The data obtained on pipes with different degrees of flexibility is shown in Figure 1 It will be noted that *K*,—the ratio of the earth pressures to the weight of material directly over the pipe—varied from 0 608 for the most flexible pipe to 1 68 for the solid plug

This chart demonstrates most conclusively that no theoretical earth pressure formula for determining reliable pressures on culvert pipe can be set up without including a factor which would vary with the flexibility of the pipe The varying flexibility of the pipe naturally produces different values for the coefficient of friction μ' exerted between the sides of the earth prism directly over the pipe and the earth alongside of it These coefficients of friction might vary from a very small amount to a maximum, known as the maximum coefficient of friction and cohesion, obtainable depending on the deflection of the pipe

It appears, therefore, that when a theoretical formula is used in the determination of culvert pipe pressures, the coefficient of friction μ' should vary to suit the conditions of relative motion of pipe and earth alongside at level of top of pipe

In order to demonstrate the change in pressures on the culvert pipe due to a slight movement of the prism material above the pipe, an apparatus was designed as part of our experiment which would permit a slight dropping of the four test pieces simultaneously After the embankment had reached a height of 12 feet the average pressure per linear foot as given by the scale readings was 4066 pounds The pipes were then dropped by intervals of one-fortieth of an inch For the first one-fortieth of an inch the pressure dropped to 2774 pounds per linear foot For a total drop of one-twentieth of an inch the scale reading was 2014 per linear foot, and for a total drop of two-tenths of an inch drop the scale reading was 357 pounds per linear foot

We have completed the field experiments on the culvert pipes and are now attempting to correlate the data thus obtained with laboratory deflections of the same test pieces that were used in the experiments From this correlation it is hoped that we may be able to establish a practical working method for the design of culvert pipes

Chairman Brosseau We now have the progress report on the Low-Cost Improved Roads Investigation