Effect of Pipe Thickness on the Behavior of Flexible Pipes with Equivalent Bending Ring Stiffness

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ABSTRACT

In current design for irrigation flexible pipeline in Japan, deflection and stress are calculated using closed-form analysis based on bending ring stiffness $EI/D^3$ ($E$: elastic modulus, $I$: geometrical moment of inertia, $D$: diameter of pipe) However, the behavior of pipe may be influenced not only by $EI/D^3$ but also by the relationship between $E$ and $I$.

In this paper, model tests for buried pipe were conducted to evaluate the effects of relationship between $E$ and $I$ on the behavior of flexible pipes with equivalent bending ring stiffness.

As a result, it was found that the larger axial stress acts on the pipe with the thinner wall, thus, the probability of buckling may be higher on thinner pipes.

KEY WORDS: Buried pipe; Model test; Strain.

INTRODUCTION

Main irrigation pipeline networks extend over 4,500km in Japan. 14% of those networks in length require repair works recently. The behavior of a buried pipeline or any underground structure is significantly influenced by the surrounding ground, the construction method employed, and various properties of the backfill material used. Particularly, the application of flexible pipes having a low stiffness will increase in the future because of their good workability and economy. Such flexible pipes having a low stiffness with thin wall tend to be easily deformed and buckling may occur as a result of an external force applied overburden pressure.

The pioneering principles of mechanics on the flexible pipe were reported to verify and determine its horizontal and vertical deflections, its bending moments, and its tangential thrusts by Marston (1913, 1930) and Spangler (1941). A full-scale experiments on flexible culverts were conducted and the design formula developed from the load hypothesis was verified by Spangler (1941). The hypothesis assumed the passive horizontal pressures distributed parabolically on the sides of a pipe. In Japan, Marston-Spangler theory is applied to Design standard for pipeline on Ministry of Agriculture, Forestry and Fisheries of Japan (1998).

The load-deflection characteristics of steel and plastic - base pipe buried in a special test container were investigated by Howard (1972(a), 1972(b), 1974). Howard (1973) proposed modulus of soil reaction $e'$ because $e'$ is a pipe - soil interaction modulus rather than a true soil modulus $e$ value originally proposed by Spangler (1941). The special laboratory tests were conducted to examine some of the relationships expressed in the Marston-Spangler theory for flexible - pipe design by Howard (1974). As the result in the load tests examined by varying the ring stiffness and soil - modulus, when the soil is well compacted beside the pipe, the pipe strength had little effect on the deflection of the pipe, as predicted by the Marston-Spangler theory.

Field buried tests and finite element method were conducted to determine the relative stiffness of the pipe with respect to the stiffness of the enveloping soil by Allgood (1972). The effect of both density of model sand ground and pipe installation type on the measured earth pressures were discussed by Tohda et al. (1995).

Ring compression theory was proposed by White (1961) as designing and building the corrugated structure according to a theory that analyzes an embedded pipe of large diameter realized a considerable saving. The theory involved a method for determining gage thickness in relation to the size of the structure and the depth of cover. In Japan, Corrugate Metal Culvert Manual (1979) was also published. However, the practical behavior of the Culvert has not clarified, as the study of the practical cases was not a lot.

Design standard for pipeline in Japan is elastic theory based on Marston-Spangler theory. However, the construction applied thin-wall pipe recently increases in Japan. The case of the buckling on thin-wall pipe is shown in Fig. 1. A tangential force acted on pipe caused the buckling. It can be considered that the formula including the normal force acted on each arc of the pipe will be needed when the thickness of pipe wall is extremely thin. With respect to thin-wall pipe, field test and numerical analysis were conducted by Kawabata et al. (1995). The study of the thin-wall pipe has not reported a lot yet.

In this paper, bending ring stiffness $EI/D^3$ is verified experimentally. Model tests for buried pipe were conducted to find effects of relationship between $E$ and $I$ on the behavior of flexible pipes with equivalent bending ring stiffness.

MODEL TEST FOR BURIED PIPE

Apparatus and Ground Material