Southern African Society for Trenchless Technology P O Box 13048 CLUBVIEW 0014

SASTT NEWS – AUGUST 2005

Editor: Joop van Wamelen, PrEng Tel: +27 (012) 841 4034 Fax: +27 (012) 841 2539 E-mail: director@sastt..org.za

Home page: http://www.sastt.org.za

Some technical advantages of using trenchless pipe installation techniques

Part 1 of a series

by Alaster Goyns

Introduction

Trenchless technology (TT) is usually promoted on the basis of its social, economic and environmental advantages. The underlying technical advantages that enable these to be realised are seldom included in the motivation of TT as an alternative. This may be one reason why decision makers are at times reticent to use the technology.

The requirements to be met by all water conduits are simple, viz:

- big enough to take the amount of water
- strong enough to carry the proposed loads
- watertight.

Also, the pipeline must last, so the materials chosen must be able to cope with any aggressive elements in the fluid being conveyed or in the external environment.

Pipelines consist of pipes made in a factory and joints made on site. Pipelines are buried so the interaction between the pipeline and the soil around it has to be considered. With trenchless installations the earth loads on pipes are significantly less, because there is little disturbance of the natural soil and in many techniques the pipe is continuous from manhole to manhole. It is due to these features that trenchless technology offers very distinct technical advantages. These notes focus on the first of these features.

Forces acting on a buried pipeline

There are two groups of forces acting on a buried pipeline once it is installed:

- primary forces due to superimposed loads such as earth, traffic and internal pressure
- secondary forces due to movements within the soil after the pipeline has been installed, resulting from moisture changes, temperature effects and additional superimposed loads such as buildings constructed over the pipeline some time after installation.

Pipes are designed to take the primary loads applied to them, and joints are designed to accommodate the movements resulting from the secondary forces that could occur. As the pipes are made in a factory they can be tested in the factory to ensure that they are strong enough to take the calculated primary loads. The pipes are jointed on site so they should be tested on site to check that the joints have been correctly made.

When pipelines are installed using trenchless techniques, the product is pulled or pushed through the soil and whether jointed or not these effects have to be taken into consideration. These loads are different from those to which the pipeline is subjected when in service and hence the structural properties required of the pipes to handle them are also different.

Calculation of loads during service

Irrespective of whether a pipeline is installed using open-cut or trenchless methods, the loads that have to be carried are essentially two-dimensional, and they can be calculated by using the Marston and Spangler theory for rigid pipes or the Iowa formulae for flexible pipes.

Rigid pipes

For rigid pipes the main determinant of load will be the installation condition, in other words whether the pipe is installed under an embankment or in a trench. These are illustrated in the figure below. A useful concept is the geostatic load, which is the load on the pipeline due to the prism of material directly over it. In a trench installation the prism load will be dependent upon the trench width and in an embankment the prism load will be dependent upon the external diameter of the pipe.

Due to frictional forces within the soil in an embankment installation, the load will always be greater than the geostatic load, because the arching action is downwards or negative. With a trench installation the load will be less than the geostatic load because the arching action is upwards. In a tunnel the vertical load will always be less than the geostatic load because both friction and cohesion transfer the load to the columns of earth on either side of the pipe. This load is dependent on the diameter of the tunnel dug to accept the pipe.

Embankment　　　　Trench　　　　Jacked

Figure 1: Comparison of pipe installation types

The calculation of earth loads for the various installation conditions is complex. However, with all of these installations there are maximum values for the earth loads that can be easily calculated and in the case of a trench or trenchless installation the earth loads will have an upper limit. The formulae and the limiting values for the various installation types are tabulated below.

Basic formula: $W_E = C_E \gamma B^2$ (1)

where W_E is total earth load in kN/m on pipeline
C_E is earth load coefficient
γ is density of fill material
B is trench width (B_t) or outside pipe diameter (B_c)

In theory the loads for complete arching action with trench loading occur when:

$$W_E = 2.63\gamma B_t^2 \text{ in sand} \quad (2)$$

$$W_E = 3.84\gamma B_c^2 \text{ in clay} \quad (3)$$

In practice the walls of a trench dug through a sandy material will not stand and equation (2) is hypothetical. However, both these equations are applicable to trenchless installations. For pipes less than 1000 mm in diameter, the trench is usually at least twice the outside pipe diameter, hence the load on the pipe in a trenchless installation will be less than one quarter of that on a pipe placed in a trench of the same depth.

With open trench installations the depth is seldom so great that full arching action and limiting loads are achieved and it would be uneconomic to use these values to determine the required pipe strength. With trenchless installations where the conduit is frequently placed at 10 diameters or more below the surface, full arching action is frequently developed. If the actual conditions are not known and it is not possible to calculate the actual superimposed load on the pipe, the use of this limiting value will give a product strength that is safe, but still economic. The reason for this is that the load is based on the tunnel diameter and not the trench width and the load is reduced by both friction and cohesion.

Flexible pipes

Irrespective of the installation type used, the load on a flexible conduit will always be less than the geostatic load calculated by using the outside diameter. This is because the flexible pipe deforms under load, settles more than the earth on either side of it and sheds the load onto this material.

As flexible pipes shed the load onto the material either side of them, the critical factor to be considered is the stiffness of the surrounding materials. These consist of the embedment and the natural soil. The design effort is thus focused on determining the details of the embedment needed to transfer the loads from the pipes to the natural material.