

Seismic Analysis of Buried Piping

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ABSTRACT

Many approaches concerning seismic evaluation of buried piping have been published in the literature. However, a concise definition of the analytical requirements, evaluation process, and design code verification is lacking.

This paper presents a brief discussion of the historical development of the current industry practice and outlines a simple but conservative evaluation procedure. Finally, it also specifies the criteria to which the evaluation needs to be met.

INTRODUCTION

Seismic analysis of buried piping has progressed over the years from conducting detailed finite element analysis representing interaction of pipe/soil interfaces, to merely concentrating on the wave passage and support anchor movement effects using beam on elastic foundation principles. The earlier efforts are primarily based on consideration of only the shear waves. This was expanded to include other wave types (e.g., compression and Rayleigh waves). Also, the axial strain of a pipe has been identified as the key factor in the buried piping design analysis. The paper by Shah and Chu (ASCE, 1974) highlighted the concept of using soil strains to determine the axial strains of a pipe. These axial strains can then be converted to pipe stresses at the straight pipe and an elbow using the procedures developed by Goodling (ASME, 1983), or at bends, tees, and other conventional configurations investigated by Yeh (ASME, 1983). The ASCE standard on buried pipes (ASCE, 1983) was published in 1983 and was based on largely the works of Shah and Chu. A more recent ASCE standard on nuclear structures (ASCE 4-86) published in 1986 (ASCE, 1986) contains simple, yet more current discussions on the buried piping. This ASCE standard on nuclear structures is one of the two documents offered for guidance by the Standard Review Plan, Revision 2 (USNRC, 1988). The other document is the NUREG-1161 (Coats, 1980) which, in addition to referencing the Shah and SMiRT 11 Transactions Vol. K (August 1991) Tokyo, Japan, © 1991

Chu paper (ASCE, 1974), also required the consideration of compression, shear, and Rayleigh waves as does in the ASCE standard 4-86 (ASCE, 1986).

Current Approaches

As presented in the ASCE 4-86 standard and NUREG-1161, the following are the required investigations for the buried piping:

1. Wave passage effects

Axial strains for straight sections of the pipe remote from anchor points, sharp bends, or intersections could be calculated either by including or neglecting soil/pipe friction force.

When friction force is neglected, the strains can be estimated as

$$(E_a)_{max} = V_{max}/(\alpha_E C) \quad (1)$$

Where $(E_a)_{max}$ is the maximum axial strain, and V_{max} is the maximum ground velocity which can be determined from the design ground response spectra for different wave types. A conservative approach would be to use the 48 in/sec value (for V_{max}) for a 1g zero period acceleration based on the Reg. Guide 1.60 design ground response spectra. Also, C is the apparent wave velocity determined from the foundation soil data. In general, the wave velocity to be used in this calculation should be no less than 3000 ft/sec. Finally, α_E is the coefficient for each wave type investigated which is defined in the following table:

Table 1 Wave Speed Coefficients α_E

Compressional Waves	Shear Waves	Rayleigh Waves
1.0	2.0	1.0

Axial strains for all three wave types, compression, shear, and Rayleigh waves should be independently calculated and combined by the square-root-sum-of-the-squares (SRSS) method.

The axial strains calculated are then to be used to calculate axial pipe stress for the straight sections, and to calculate the bending moments at the elbows, bends, and tee connections using the formulas developed by Shah and Chu, (ASCE, 1974) and Goodling (ASME, 1983), and Yeh (ASME, 1983).

2. Anchor Point Movements

In addition to calculating pipe stresses due to the wave passage effect, the effect of the anchor point movements should

also be determined using the beam on elastic foundation principles (Hetenyi, 1967).

It is generally appropriate to consider the adjacent anchor point movements as out of phase. Therefore, the relative movements will need to be summed absolutely.

Forces and strains associated with the relative movement of anchor points should then be combined with the results from the wave passage effects using the SRSS approach.

3. Lateral Soil Pressure

It is generally acceptable to consider that the waves transmitting through the bedrock to the surface are vertically propagating waves. The earth pressure will force the pipe to move with the surrounding soil. In general, the soil wave length is considerably longer than the pipe length in a nuclear plant design. Therefore, it is unlikely that the pipe will have the same maximum curvature as the soil waves. Furthermore, the maximum bending stresses resulting from the earth pressure normally do not occur at the bends and elbows. Rather, they are more likely to occur at straight portions of the pipes, different from the wave passage and anchor movement effects. When lateral soil pressure effect is to be included, it can be calculated as recommended by Yeh (ASME, 1983). However, Yeh also converted this bending stress to strain and chose to combine this strain with the axial strain. This is unnecessarily conservative and not recommended. Instead, the bending stress should be combined with the stresses from the effect of the axial strains by SRSS.

It should be noted that again, as in the calculation of axial strains, all three potential wave types, (compressional, shear, and Rayleigh waves) should be included in the calculation and the results combined using the SRSS approach.

4. Code Comparison

For steel pipes, the bending moments calculated should be assessed using Equation 9 of the Section III ASME Code for occasional loads. It should be noted that deadweight stress can be neglected in the Code comparison. Since earthquake moment loads on buried piping come primarily from the effects of the axial strains and anchor movements and not from the inertia response, it appears reasonable to treat these loads as secondary. Therefore, one may evaluate the moment loads in Equation 10 instead. Also, Equation 10 is intended only for the upset condition anchor movement loads. For faulted condition anchor movement moment loads, the allowable loads should be substantially increased. An allowable stress limit as high as $2S_y$ could be justified from fatigue considerations.

5. Pipe Components for Evaluation

Special attention should be given to connections, splices, tees, bellows, saddle supports and other restrains.

6. Directional Motion

All three input directions should be considered and the stresses combined using the SRSS approach.

SUMMARY

A review of the seismic analysis requirements for buried piping has been presented based on the guidance offered by the Standard Review Plan. A simple yet conservative evaluation approach has been outlined utilizing the historical development on the subject. Discussion concerning current industry practices is also presented.

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