# Design Approach for Circular Buried Conduits

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Recent developments in the finite element method have made adequate evaluation of the response of buried conduits possible. However, due to the difficulties associated with the proper representation of soil properties, the direct application of the method is not warranted for most design problems. A possible compromise is the use of a generalized graphical procedure based on numerous finite element solutions. A brief outline of a proposed procedure follows.

## BACKGROUND

The curves obtained by Kay and Krizek (4) and shown in Figures 1, 2, and 3 allow the determination of the response of an elastic tube deeply buried in an elastic medium and subject to an overpressure. The dimensionless response parameters for deflection, bending moment, and thrust are given in terms of Poisson's ratio for the medium and a dimensionless bending flexibility parameter for the conditions of both slip and no slip between the conduit wall and the medium. These figures were developed on the assumption that no tangential or hoop compression of the tube wall is possible, and, for many applications to the buried conduit problem, little error arises from this source. However, for low modulus plastic pipes and sectional plate metal conduits for which some joint slip may occur, it may be necessary to account for tangential compressibility. Appropriate correction factors derived from the Burns and Richard (2) equations are shown in Figures 4, 5, and 6.

Extensive finite element studies have been made on the effects of finite-cover heights and the presence of an in situ soil that has different compressibility characteristics from those of the fill. These results indicate that the finite-cover height should be taken into account by correction factors such as can be obtained from Figures 7, 8, and 9. Finally, curves such as those in Figure 10 provide an approximate equivalent modulus that accounts for the effect of a difference between the modulus of the in situ soil and that of the compacted fill.

A nonlinear, stress-dependent soil modulus may be accounted for by the computation of response in a stepwise manner of progressive load addition (3), but, with the present uncertainties associated with soil modulus determinations, the accuracy obtained by the use of an average tangent modulus over the pertinent stress range is probably sufficient.

Figures 7, 8, and 9 show that the correction required to account for the finite-cover height for most conventional flexible conduits is small and could be neglected. This implies that, for many flexible conduit applications, once an equivalent soil modulus value is determined, the response parameters may be determined from Figures 1, 2, and 3 alone. However, with increased wall stiffness, the consideration of finite-cover height in the analysis becomes more important.

## SUGGESTED PROCEDURE

1. Obtain the constrained modulus characteristics for both the in situ soil and the compacted fill as functions of overburden stress by available methods. Select trial values for the conduit radius (R), the conduit material modulus (E), the conduit wall moment of inertia per unit length (I), and the conduit wall area per unit length (A) for the pipe design.
2. Determine the equivalent homogeneous modulus characteristic as a function of overburden stress from families of charts such as Figure 10.
3. Consider the response of interest to be that associated with the addition of fill above the crown. For a nonlinear analysis, divide the overburden into a number of layers above the crown; otherwise, consider the fill over the crown to consist of a single layer. The significance of nonlinearity may be assessed by analyzing with the total fill as a single layer and then repeating the analysis on a multilayer basis.
4. Determine the average constrained modulus ($M_s$) associated with the stress increase at the conduit centerline due to the addition of a layer of fill.
5. Determine the conduit flexibility parameter ($M_sR^3/EI$).

Publication of this paper sponsored by Committee on Subsurface Soil-Structure Interaction.

6. Obtain the deflection, thrust, and bending moment parameters from Figures 1, 2, and 3 and compute the deflection (w′), thrust (T′), and bending moment (M′) for the layer.

7. Obtain $F_w$, $F_T$, and $F_M$, the respective correction factors for tangential compression, from Figures 4, 5, and 6.

8. Obtain $C_w$, $C_T$, and $C_M$, the respective correction factors for finite-cover height, from Figures 7, 8, and 9.

9. Obtain the corrected response values for the layer from

$$w = w'F_w C_w \tag{1}$$

$$T = T'F_T C_T \tag{2}$$

$$M = M'F_M C_M \tag{3}$$

Figure 1. Deformation parameter versus bending flexibility parameter.

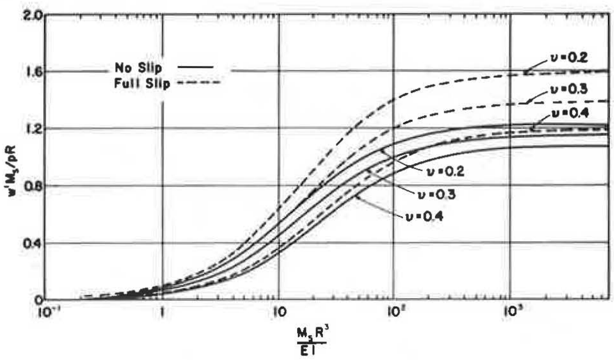



Figure 2. Thrust parameter versus bending flexibility parameter.

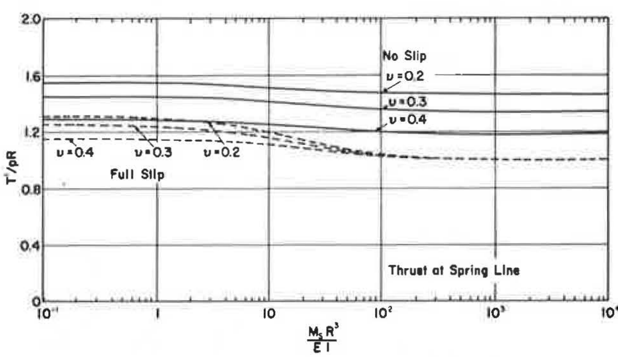
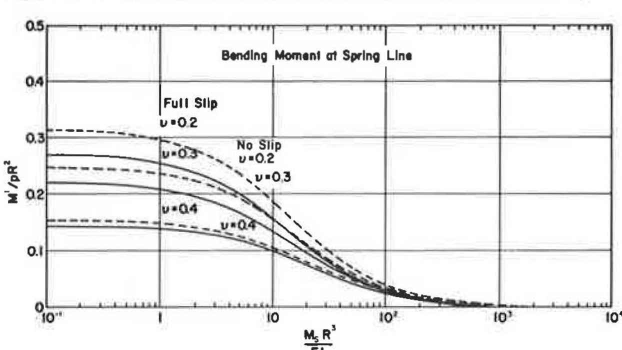



Figure 3. Moment parameter versus bending flexibility parameter.




10. Repeat steps 4 through 9 for each layer and sum the layer responses to obtain the total responses. Compare the responses to appropriate design criteria and redesign if necessary.

Figure 4. Tangential compressibility correction for deflection w.

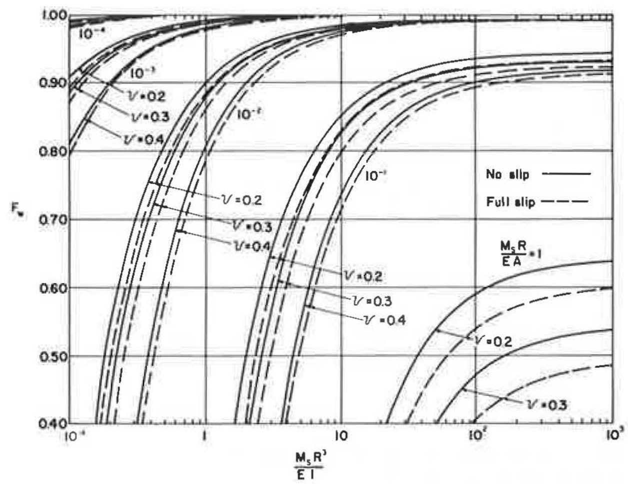



Figure 5. Tangential compressibility correction for thrust T.

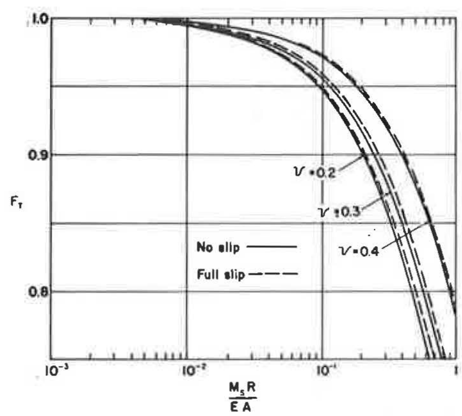



Figure 6. Tangential compressibility correction for bending moment M.

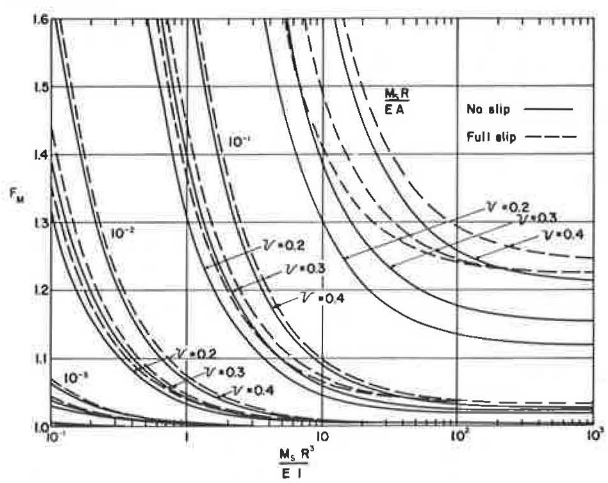


Figure 7. Layer-height correction factor for deflection w (no-slip condition and $\nu = 0.3$).

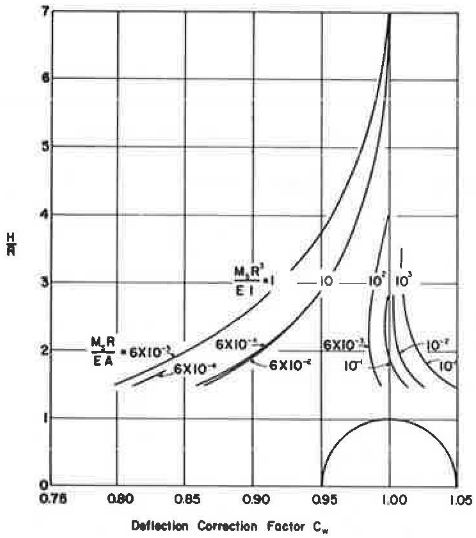



Figure 8. Layer-height correction factor for thrust T (no-slip condition and $\nu = 0.3$).

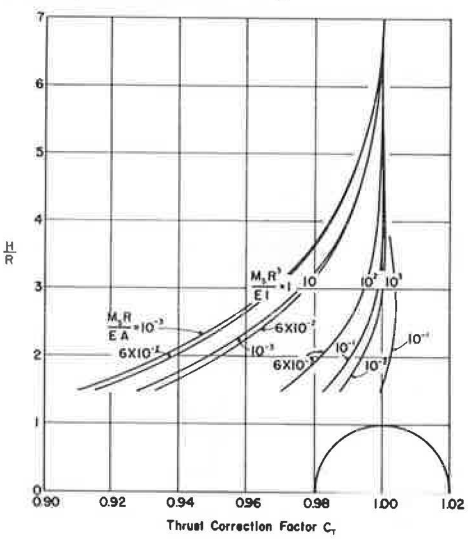



Figure 9. Layer-height correction factor for moment M (no-slip condition and $\nu = 0.3$).

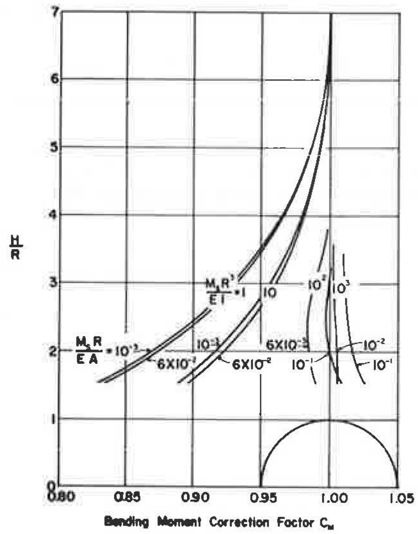
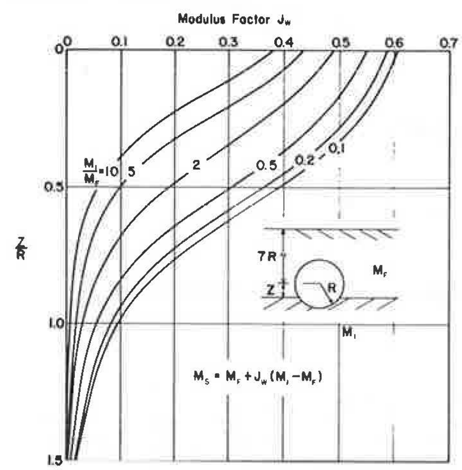



Figure 10. Equivalent modulus factor for deflection w, two-layer system (no-slip condition, deep cover, $\nu = 0.3$, $M_F R^3/EI = 1.16 \times 10^2$, and $M_F R/EA = 6.12 \times 10^{-2}$).




## CONCLUDING REMARKS

The foregoing is a very brief summary of the proposed design procedure. Details of the construction of the charts, discussion of the limitations and advantages of the approach, and worked examples are given elsewhere (1, 3).

## REFERENCES

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