

## NONLINEAR FINITE ELEMENT-BASED INVESTIGATION OF THE EFFECT OF BEDDING THICKNESS ON UNDERGROUND PIPE

The pipe-soil interaction is studied by using the finite element software, ABAQUS/CAE Version 6.5-1 as a symmetric model of embankment installation in Figure 1 to study the effect of bedding property and thickness on pipe-soil interaction with increase in the height of fill. A three-dimensional finite element model (FEM) of the concrete pipe and surrounding soil is developed. The FEM is capable of simulating material, geometric, and contact nonlinearities which employs a nonlinear incremental solution algorithm. Several different element types and mesh size were tested to obtain the optimum converged mesh. These elements were eight-noded linear brick (C3D8R) and six-noded linear triangular prism (C3D6) for modeling of the concrete pipe and surrounding soil as shown in figure 2. The behavior of the 3-D model is investigated by varying the pipe diameter, backfill height, bedding thickness, and bedding material. Three material constitutive relationships of soil involving in the model are gravelly sand (Sn), sandy silt (Si), and silty clay (CL). Figures 3 and 4 show the typical FEM results.

To study the effect of bedding thickness on the pipe wall, due to the increment of backfill soil depth, contact elements were employed in the interface between each two regions. The lateral boundaries and model length were also studied for the converged solution. A parametric study was conducted to study the effects of bedding thicknesses 3 in (7.5 cm), 5 in (12.5 cm), 7 in (17.5 cm), and 9 in (22.5 cm) with backfill heights 20 ft (6 m), 40 ft (12 m), 60 ft (18 m), 80 ft (24 m), and 100 ft (30 m). The different types of material used for the inside bedding zone are as follows: Si70; Si90; Sn85; and Sn90. The results show the increase in bedding thickness reduces tensile stress at crown, springline, and especially invert of the pipe wall depending on the material property. This means the change in material property and compaction level has a greater effect on the reduction of tensile stresses than the effect from the variation of bedding thicknesses as shown in Figures 5 and 6 for instance. Also, materials with lower bedding stiffness (high deformability characteristics) cause greater reduction in induced stresses. This study shows that for commonly used bedding material (Sn90), the

effect of the increase in bedding thickness has a minimal effect on stress reduction of the pipes studied.

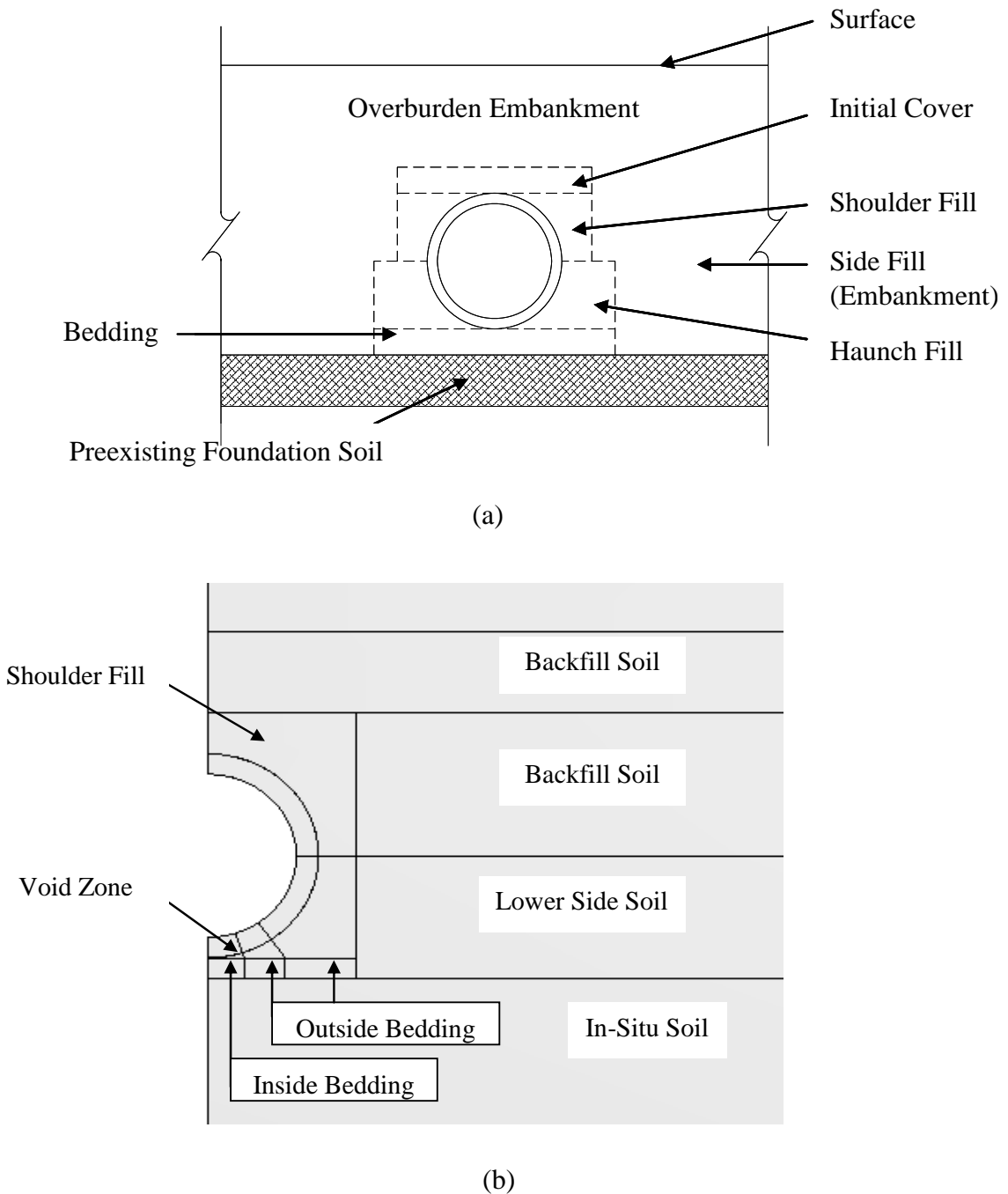


Figure 1 Embankment Installation (Positive Projection); (a) Typical details and (b) Soil zones used in the symmetric FEM model

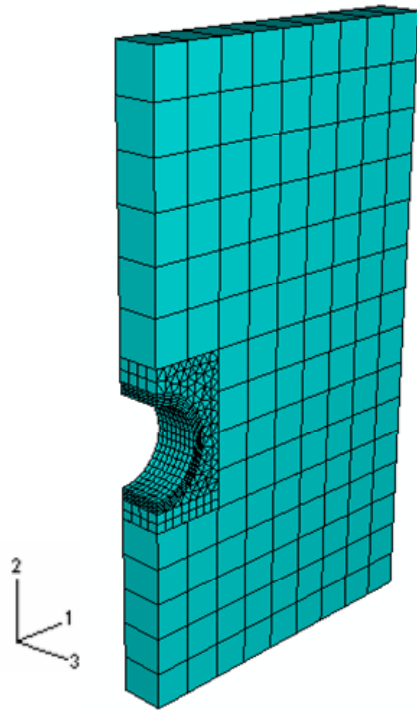


Figure 2 Converged Finite Element Mesh

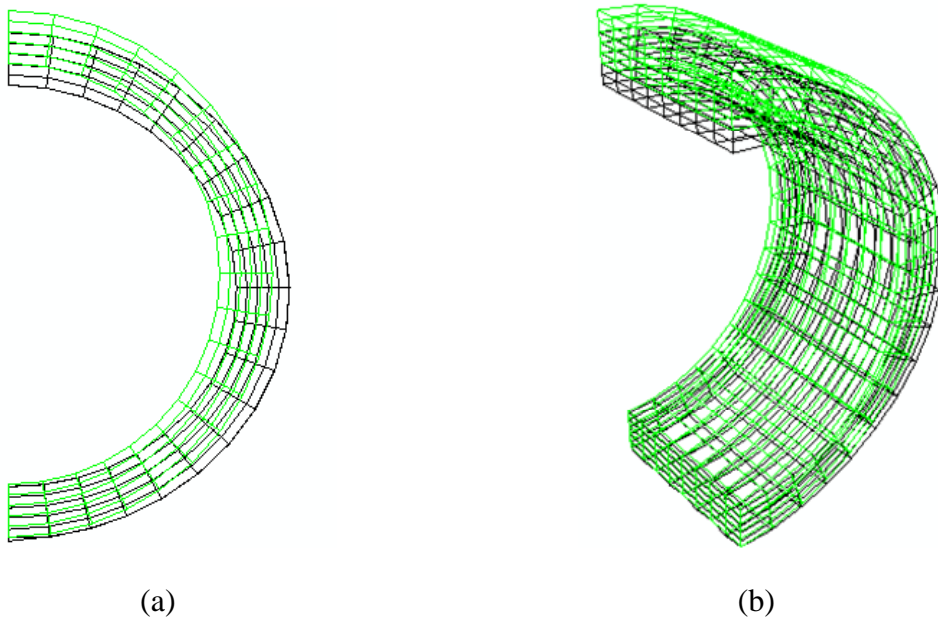
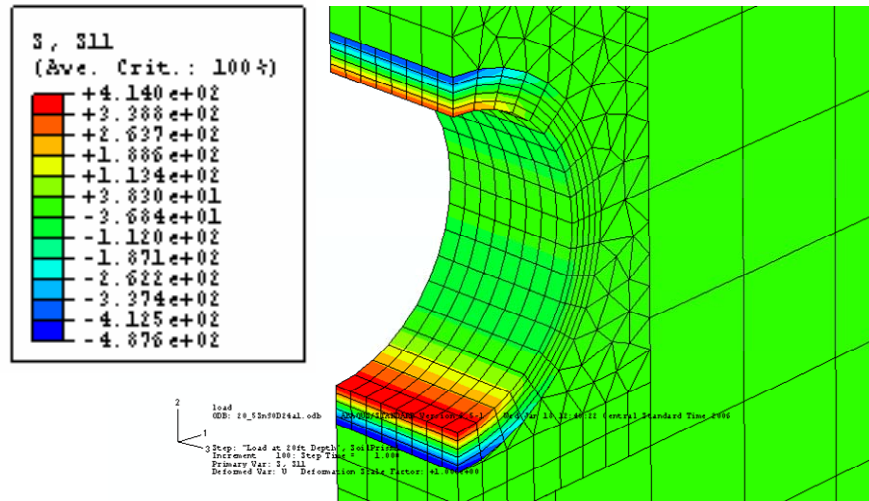
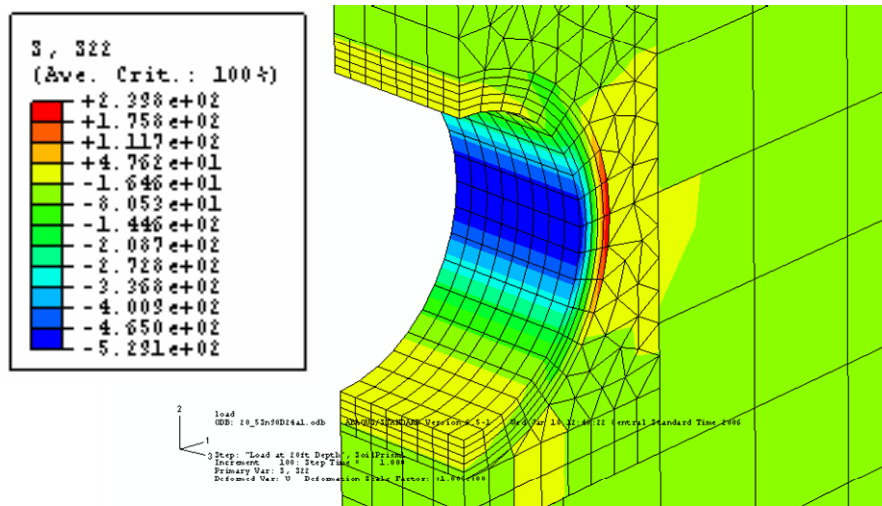


Figure 3 Typical deflection shape of the pipe wall; (a) In plane 1-2 and (b) In 3-dimension view (The green lines show the original shape, and the black lines show the deformed shape)

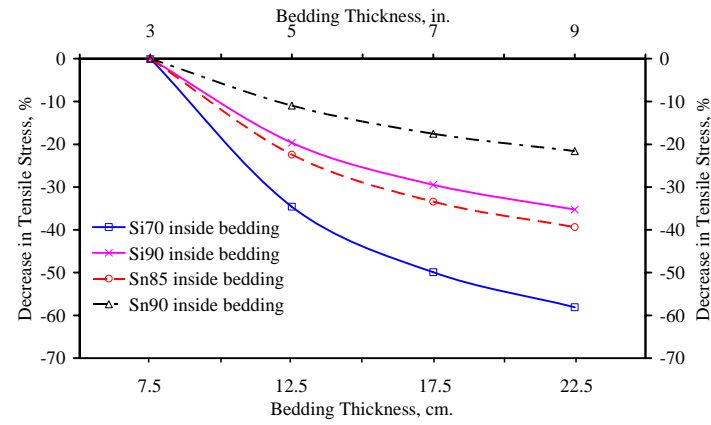


(a)

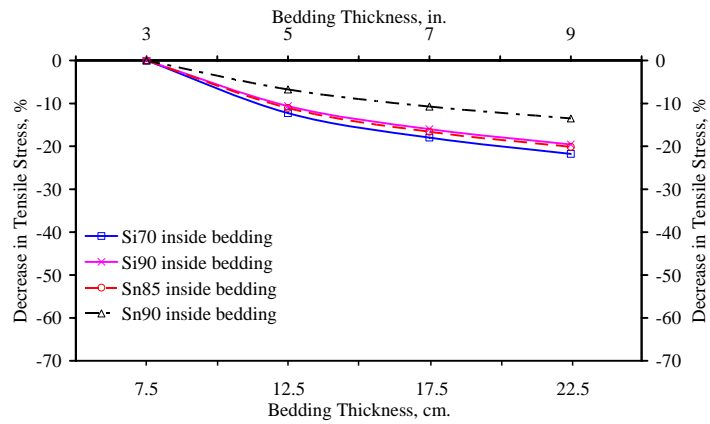


(b)

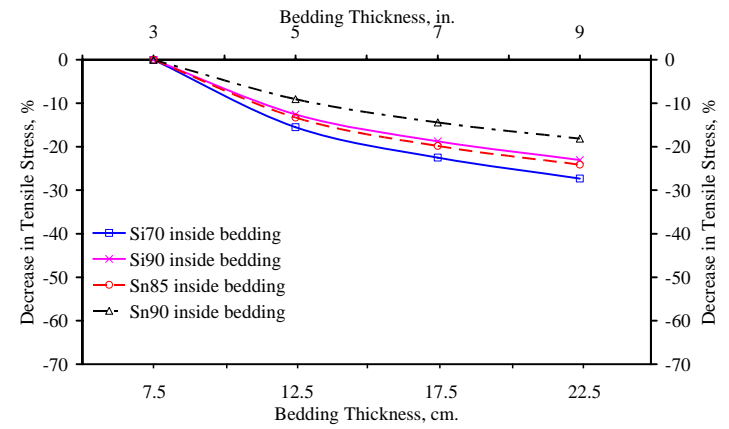
Figure 4 Typical stress contour in the pipe wall; (a) Hoop stresses at invert and crown and (b) Hoop stresses at springline



(a)

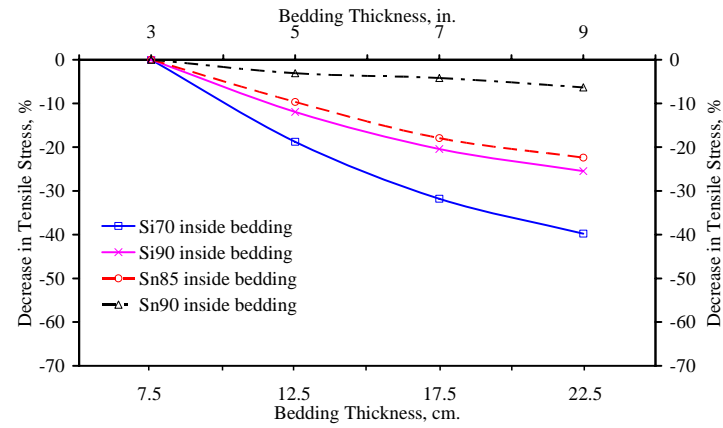


(b)

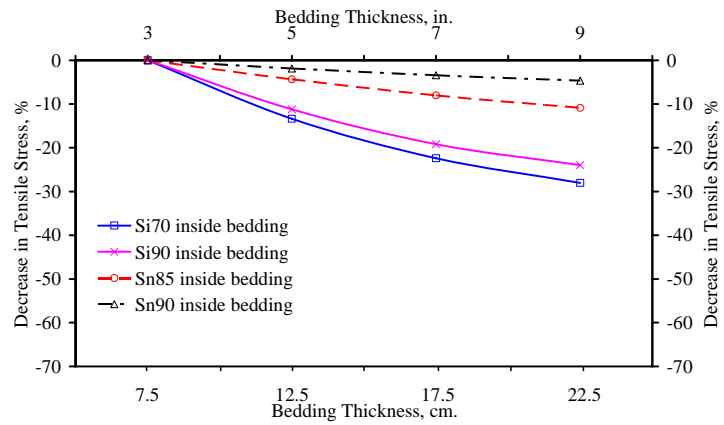


(c)

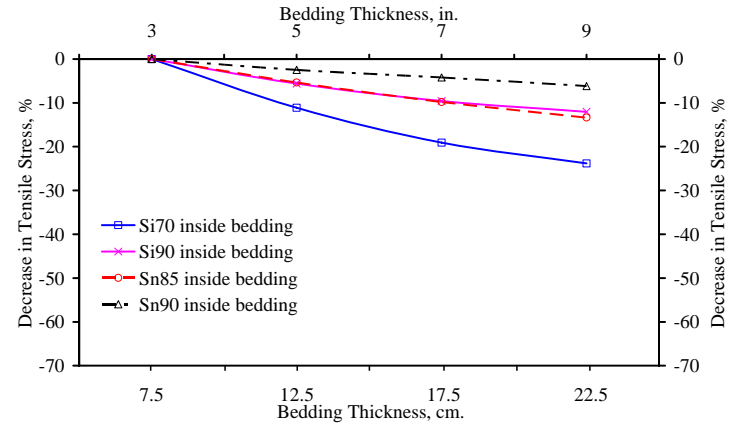
Figure 5 Decrease in tensile stresses versus bedding thicknesses for 24in-dia pipe in 20ft-height backfill;  
 (a) At invert, (b) At crown, and (c) At springline



(a)



(b)



(c)

Figure 6 Decrease in tensile stresses versus bedding thicknesses for 24in-dia pipe in 100ft-height backfill; (a) At invert, (b) At crown, and (c) At springline