SECTION 7
WELDED STEEL PIPELINE DAMAGE

In this section, a case study of damage to a welded steel pipeline in Mexico City caused by the 1985 Michoacan Earthquake is presented. The water pipeline in question is located in "Ciudad Nezahualcoyotl" in the state of Mexico. There are other welded steel pipelines in Mexico City operated by PEMEX, the state owned oil and gas company. However, the authors were unable to obtain information about seismic performance of PEMEX facilities.

Physical characteristics of the Ciudad Nezahualcoyotl water pipeline and information about the observed seismic damage is presented. In addition, an analysis procedure developed previously by the second author is used to estimate pipeline stress induced by seismic wave propagation. This estimated stress is slightly less than the local compressional buckling stress for the pipeline.

7.1 Physical Characteristics and Observed Damage

The Ciudad Nezahualcoyotl pipeline is the only major underground welded steel pipeline in the Metropolitan Mexico City water system. It is located in the State of Mexico, southeast of the airport and north of Cerro de la Estrella and runs parallel to Avenue Ignacio Zaragoza. The pipeline is about 9km in length and was constructed in the early 1970's of API 120 X-42 grade steel (yield stress = 42 ksi). The pipeline's diameter is 42 in. and it has a wall thickness of 5/16 in. The pipe centerline is about 6.35 ft. below the ground surface. At the time of the earthquake, the internal operating pressure was between 40 and 60 psi and the flow was about 1.6 m^3/sec.

The subsoil profile for the general region consists of 40 m of very soft clay with a shear wave velocity (V_s) of about 40 m/sec. Below the top layer are two stiffer strata with thicknesses of 80m and 400m, and shear wave velocities of 300 m/sec and 500 m/sec respectively. These three layers sit atop rock with a shear wave velocity of about 1250 m/sec. This soil profile is shown in figure 7-1.

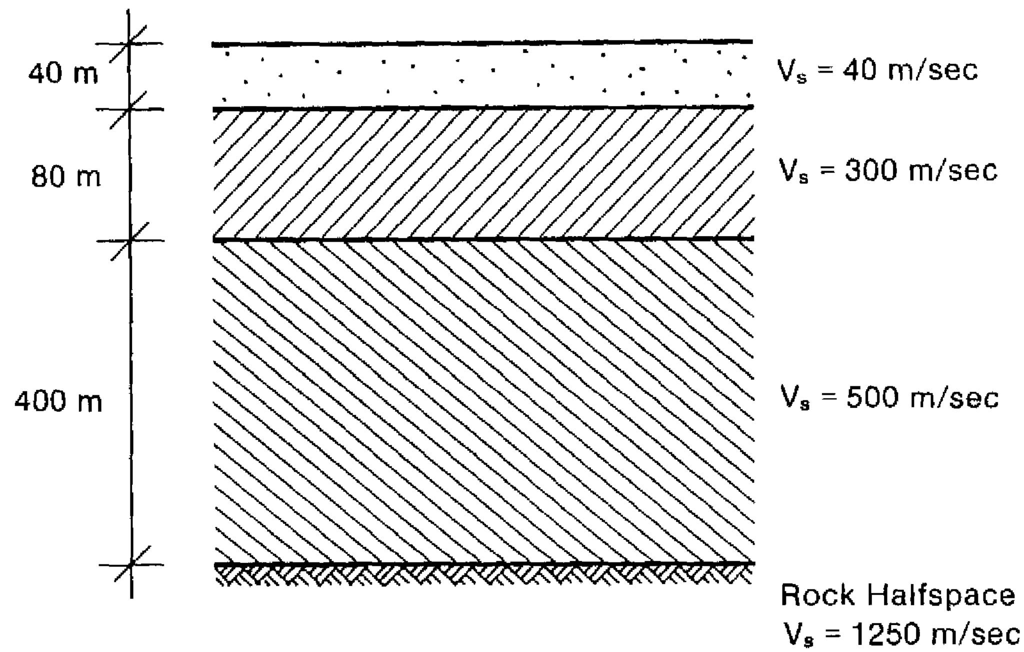

FIGURE 7-1 Estimated Soil Profile For Ciudad Nezahualcoyotl

Seismic damage occurred at a minimum of eight locations along the 9 km length of the line. At six of these points, circumferential cracks resulting from wrinkling deformations (ie, local buckling) were observed as shown in figures 7-2 and 7-3. In addition, a 36"ϕ butterfly valve located in an air relief valve box, was broken, as shown in figure 7-4. Breaks also occurred at a welded joint along the pipeline and on a 14"ϕ asbestos cement pipe connection to the steel pipeline. The locations of these failures are shown in figure 7-5. It is believed however that there were more failures than those shown in figure 7-5 since several engineers involved in the repair work reported that failures occurred consistently at 300 to 500 m intervals along the line. As mentioned previously, there was no evidence of liquefaction in the metropolitan area. In addition there was no evidence of permanent ground deformation in the metropolitan area, except for the previously mentioned subsidence. Hence it would appear that the seismic damage to the welded Ciudad Nezahualcoyotl pipeline as well as the other segmented pipelines in the water system was due to seismic wave propagation.

7.2 Stress Analysis

An analysis procedure developed by the second author [11] is herein used to estimate the compressive strain induced in the Nezahualocoyotl pipeline by seismic wave propagation. The procedure compares axial strain in the soil with the strain in a continuous pipeline due to soil friction along its length. It is assumed that the soil strain is due to Rayleigh Wave (surface wave) propagation along the pipeline axis. This soil strain is a decreasing function of separation distance or wavelength. The strain due to friction at the soil-pipeline interface is an increasing function of separation distance or wavelength. At a particular separation distance, that is for a particular wavelength, the friction strain matches the soil strain. This unique strain then becomes the peak strain induced in a continuous pipeline.

7.2.1 Soil Strain

The maximum horizontal strain in the soil is based upon the assumption of a Rayleigh wave (R-wave) propagating in the direction of the pipeline axis. This longitudinal soil strain ε_s between two sites separated by a distance L

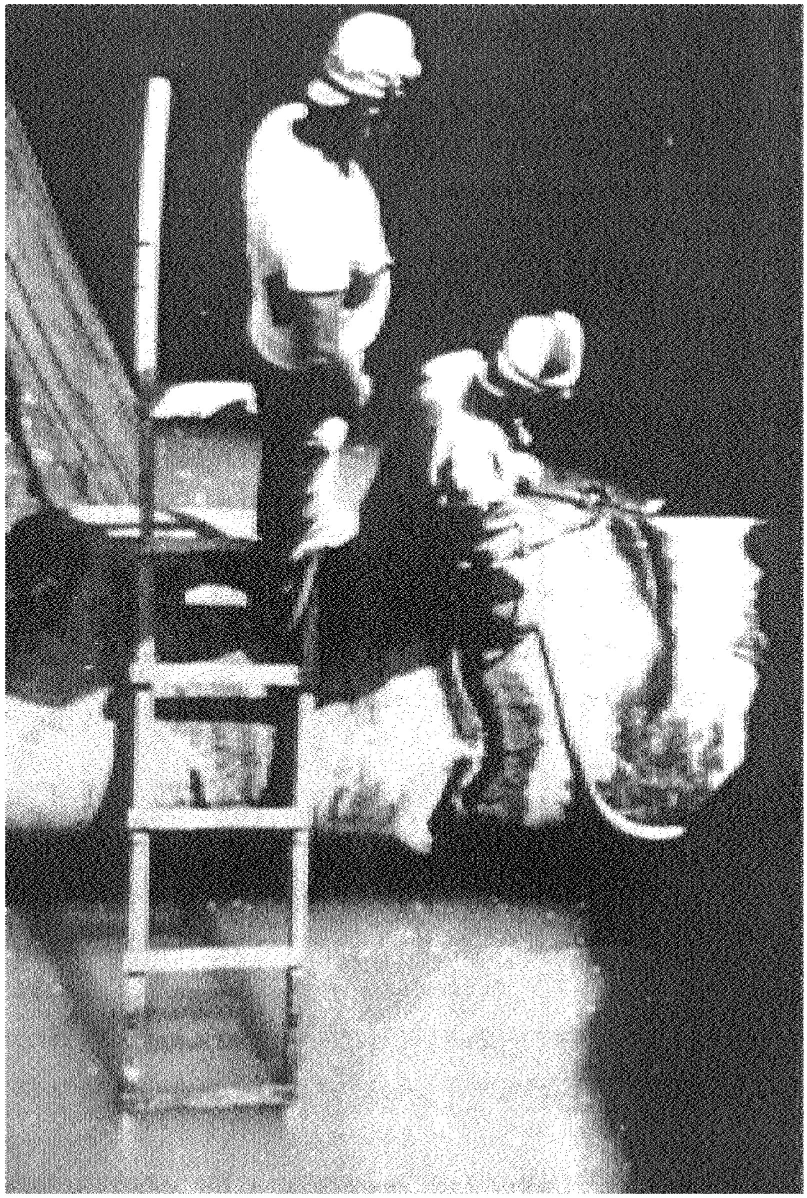

FIGURE 7-2 Local Buckling Failure Of Ciudad Nezahualocoyotl Pipeline - 1985 Michoacan Earthquake