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UPHEAVAL BUCKLING OF PIPELINES

Upheaval buckling of a pipeline is manifested by a buried pipeline which “pops out of the ground”. This occurs when the resistance of the soil backfill is insufficient to restrain the pipeline from bowing upwards. Once the downward resistance of the soil cover is exceeded, the extent of the bowing or buckling will be mainly determined by the release of potential compressive energy in the pipe, pipe size, and burial conditions. In certain environments, this is a critical mode of failure, yet it is not covered in the ASME code. All the ASME code states is “The maximum longitudinal stress due to axial and bending loads during installation and operation shall be limited to a value that prevents pipe buckling or otherwise impairs the serviceability of the installed pipeline. [403.3.1]” Therefore, establishing the risk of the potential for upheaval buckling is strongly a function of the practitioner’s knowledge and experience.

The upheaval buckling mode of failure has been recognized in sea bottoms, in the desert, and in mining regions. Figures 1 and 2 show examples of upheaval buckling from pipelines in the desert and in mining terrain, respectively. The upward bowing of the pipeline from mining was the result of land subsidence which includes not only vertical displacement, but significant horizontal displacement.

FIGURE 1 UPHEAVAL BUCKLING OF A PIPELINE IN DESERT TERRAIN (TR ENGINEERING CONSULTANCY)

FIGURE 2 UPHEAVAL BUCKLING OF A PIPELINE FROM LAND SUBSIDENCE FROM MINING

The most common ground movement condition which can result in upheaval buckling or bowing is the result of the compressive lateral movements from subsidence above mining, (see Engineering UPDATE #25) although there are other geohazards that are less likely to cause this

condition. Upheaval buckling from mining is illustrated in Figure 3. Here, the pipeline is considered to be subsided and affected by the ground/pipe slip resistance from compressive horizontal displacements. This slip resistance results in compression in the pipeline. It is important to note that a slip of only a fraction of an inch will develop the ultimate slip resistance. Moreover, the vertical curvature in the line plays a key role in the upheaval potential where there was a pre-existing convex curvature present in the pipe as illustrated in Figure 3. Here, the induced axial pipe compression develops an eccentricity and moment which results in the pipe being susceptible to upward bowing. Conversely, concave lines cause downward bowing pressures and thus are not prone to upheaval.

Conditions which increase the susceptibility of a buried pipeline to upheaval buckling are:

- Excessive total axial compressive stress
- Insufficient pipe constraints
- Convex pipe curvature.

The development of the resistance to slip, which causes compressive axial stress mainly depends upon the ambient backfill friction/adhesion properties, burial depth, and pipe coating type. The downward pipe constraints are typically associated with soil backfill density, depth, and strength. Whereas convex pipe curvature can more typically result from the surface topography with constant burial depth (see Figure 3) and crossovers.

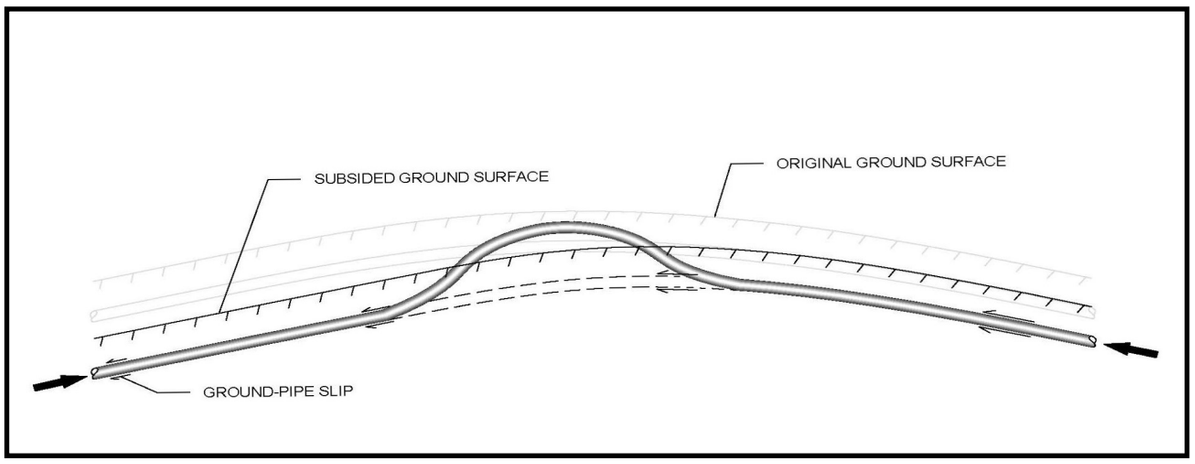

FIGURE 3 ILLUSTRATION OF UPHEAVAL BUCKLING/BOWING FROM COMPRESSIVE GROUND MOVEMENT FROM MINE SUBSIDENCE

There are a number of ways that a pipeline can be mitigated against upheaval buckling/bowing. The most cost-effective measures are highly dependent upon the site conditions.

Other MEA Publications that may be of Interest:

UPDATE #4 Improvement of Mine Support Saves Pipeline From Subsidence Event

UPDATE #25 Transmission Pipeline Subsidence From Mining

UPDATE #44 Property Management System for Geotechnical Risks

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FOR MORE INFORMATION: There is a significant amount of additional information that is available on the above subject. For more information, please contact MEA at the address listed below.

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