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THE SIGNIFICANT DIFFERENCE IN CALCULATING PIPELINE STRESSES FROM PREDICTED SUBSIDENCE MOVEMENT USING TRADITIONAL OR NUMERICAL VS. STATISTICAL MODELS

OVERVIEW

Statistical analysis of determining the subsidence induced stress to any structure is far more representative in quantifying the chance damage. This is important because to arrest this geohazard, numerical analyses are commonly performed to predict the pipe behavior exposed to subsidence ground movements without the use of such statistical data analysis.

Mine subsidence ground movements can cause significant stresses and failure to a pipeline if left unabated. In order to assess the subsidence induced pipe stress the nature and magnitude of the vertical and horizontal ground movement along the pipeline must be predicted. Therefore the prediction method plays a crucial role in the expected behavior of the pipeline. However, when developed the traditional mine subsidence prediction tools did not have in mind the assessment of the statistical range of critical movements the structure would be exposed to. Instead, these tools were based on the objective of best representing the subsidence case history data collected and not focused the critical behavior that a particular structure would face. When examining subsidence case data it can be seen that the nature and magnitude of subsidence movements are significantly variable. Therefore it is not known when using such prediction techniques how conservative or risky the calculated pipe stresses are. This also applies to numerical modeling the expected movements where the level of certainty is unknown which requires numerous model assumptions to be made of unknown statistical representation.

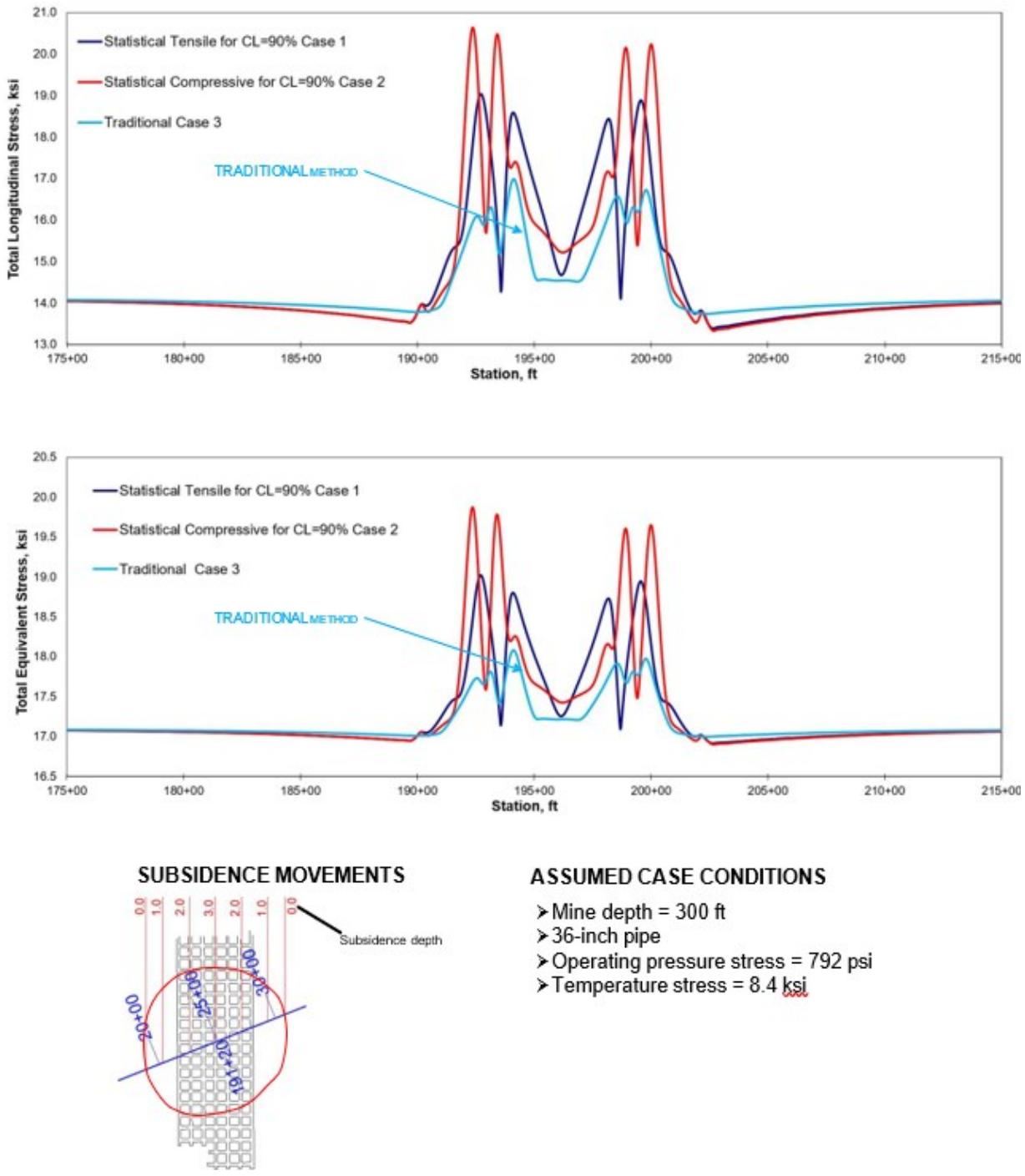


FIGURE 1 PREDICTED PIPE STRESSES FROM SUBSIDENCE OVER A ROOM AND PILLAR AT 300FT DEPTH USING A TRADITIONAL VERSUS SUBSIDENCE PREDICTION METHODS

EXAMPLES OF TRADITIONAL VS. STATISTICAL PREDICTIONS

Two examples are given below to illustrate the differences in the calculated pipe stresses from the most common methodologies used to predict the imposed subsidence ground movements to that when using the statistical method.

The first example is considering the effect of a subsidence from room and pillar mine collapse at a depth at 300ft on a 36in diameter buried pipe at 3ft depth. In this case, given the larger diameter, the most critical deformation imposed by subsidence on the pipeline would be related to bending. Therefore from a statistical perspective the focus is the likelihood of the magnitude of maximum subsidence curvature (S''_{max}) due to tension and compression (i.e., Case 1 & Case 2 in Figure 1) that can occur, respectively. Therefore, the risk level severity of the pipeline is primarily controlled by the statistical variation of S''_{max} (in terms of the confidence level of the S''_{max} prediction) for the project site using the 100's of case histories MEA has collected. Other such subsidence parameter values are selected to

statistically maximize the pipe stress to the selected risk level (e.g., horizontal ground displacement). For the same pipe-mine scenario a more traditional subsidence prediction was also applied which anonymously predicts (i.e., unknown confidence level) the pipe stresses. As can be seen in Figure 1 the calculated total longitudinal and equivalent stresses along a straight line (no bends) at a confidence level of 90% by the statistical method results in up to a 22% and 17% respective increase compared to the anonymous traditional methodology.

To demonstrate a different statistical crucial ground movement focus based on the pipe-mine conditions in question, a second example is provided. In this case, subsidence over a longwall mine panel was considered that was 1600ft deep with a 6in diameter pipe buried 3ft deep with bends exposed to the resulting subsidence. In this case, given the bending flexibility of the line the statistical trials would be related to maximizing the axial induced tensile or compressive stress (i.e. Cases 1 and 2 respectively) from ground-pipe slippage resistance from horizontal ground displacement despite over 5.8ft of vertical subsidence expected. Trial case 3 should also be considered in the statistical analysis because the bends in the pipe expose the pipe to concentrated bending for the lateral ground movement. In Figure 2, the calculated longitudinal and equivalent stresses are plotted for the 3 cases using the statistical method of a 90% confidence level and for the anomymous traditional subsidence prediction method (Case 4). As can be seen in Figure 2 there is an increase of up to 64% in total longitudinal stress and 70% in total equivalent stress for the predicted statistical approach over the traditional method.

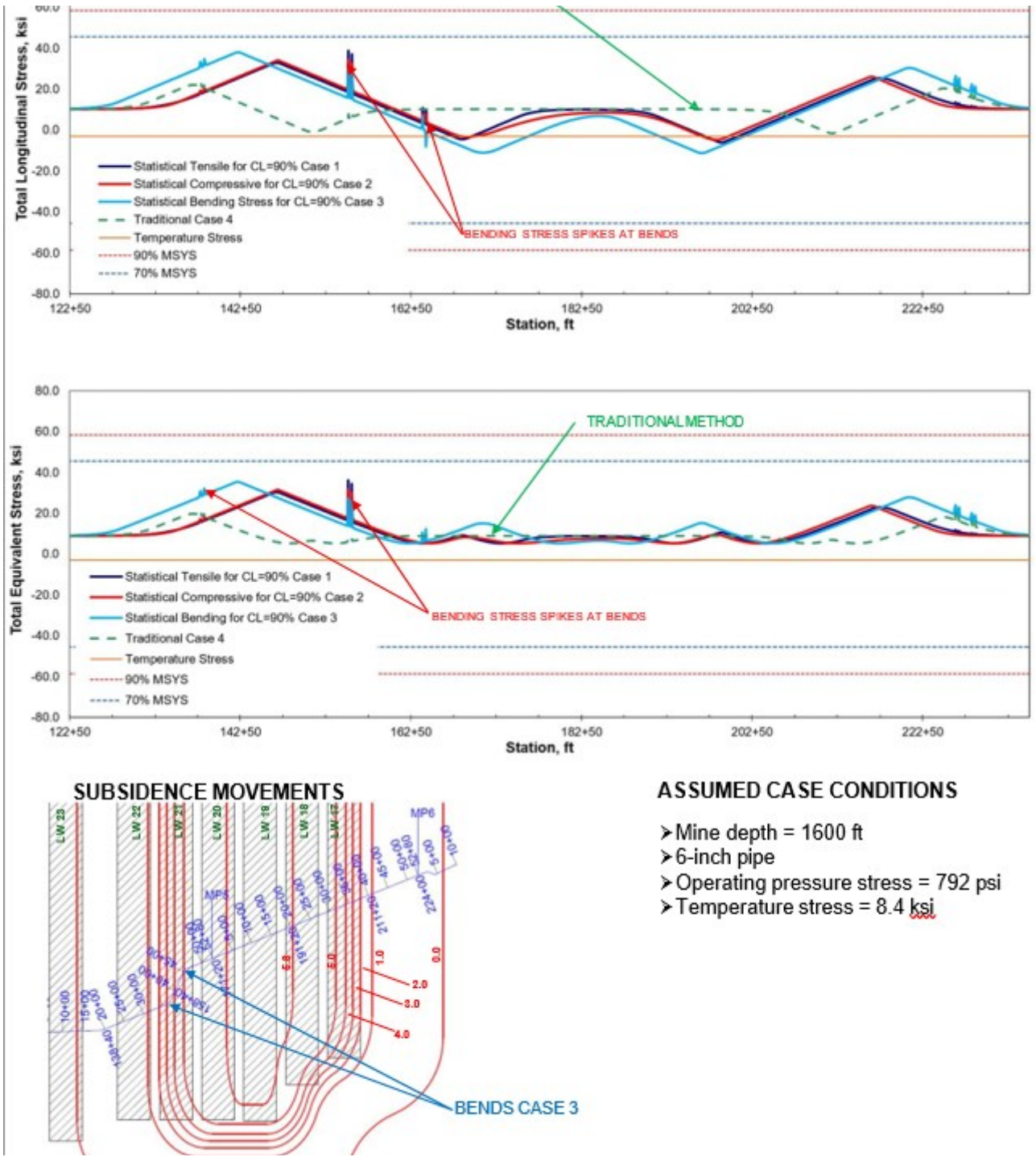


FIGURE 2 PREDICTED PIPE STRESSES FROM SUBSIDENCE OVER LONGWALL PANELS AT 1600FT DEPTH USING A TRADITIONAL VERSUS STATISTICAL SUBSIDENCE PREDICTION METHODS

Note, the above examples are for illustration purposes and do not consider the pipe upheaval potential (see UPDATE entitled Upheaval Buckling of Pipelines)

CONCLUSION

Common industry standard subsidence prediction methods were not built to directly assess subsidence-structure interaction. Therefore, the level of risk in the calculated pipe stresses using these methods are unknown, and thus providing significant variation and uncertainty in the results depicting arbitrary margins of safety. Therefore, the best approach to assess such risk for subsidence-structure interaction assessments is a true probalistic statistical analysis based on an adequate case history database considering the critical modes of deformation. This approach applies to any predicted ground movement – structure interaction concerns.

Reference:

Marino, G.G., Osouli, A., Elgendy, M., 2016, Utilization of Historical Subsidence Data for Attendant Damage Evaluation, International Journal of Geomechanics, July 26, 2016.

Other MEA Publications that may be of Interest:

Engineering UPDATE 44: Property Management System for Geotechnical Risks

Engineering UPDATE 54: Handling Potential Mine Subsidence at a Project Site

Engineering UPDATE 62: Establishing Pipeline Geohazard Mitigation Protocols

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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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