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THE SIGNIFICANCE OF ANISOTROPIC GEOSTATIC STRESS FIELD CONCERNING THE HILLTOP FARM GAS STORAGE CAVERNS IN CHESHIRE, UK

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Abstract

The *in situ* geostatic stresses in the earth's crust have been widely recognized as a basic parameter necessary in the engineering design of underground structures. More specifically, the analysis of the geomechanical stability of gas storage salt caverns is greatly dependent upon the magnitudes of these primitive, otherwise known as geostatic stresses, naturally existing in the underground formations before the leaching of the caverns. In salt formations an isotropic geostatic stress field is typically assumed, i.e. the vertical and the two horizontal geostatic stress components are taken to be equal implying that $\sigma_H = \sigma_h$ and $k_o = 1$ where k_o is the ratio of the horizontal geostatic stress σ_h to the vertical lithostatic stress σ_v. In the absence of any *in situ* stress measurements, this assumption is customarily accepted as basis of design in determining the maximum permissible pressure in a gas storage cavern.

However, in reviewing the implementation of hydraulic fracture tests, Horvath and Wille (2009) identified that fracture tests have been observed to provide formation pressure values about 5% higher than the vertical stress inferred from density logging. In addition, in a series of hydraulic fracturing measurements of the *in situ* stress at the Conway Underground East and Mitchell storage facilities in Kansas, USA, the minimum horizontal stress was at least equal to the vertical lithostatic at Conway Underground East and possibly 20% to 25% higher than the corresponding vertical lithostatic at Mitchell (Doe and Osnes, 2006). Further evidence of the anisotropic geostatic stress field in salt formations was provided by Schreiner *et al* (2004) whereby pneumatic frac tests in a salt dome of northeast Germany at various depths between 900 m and 1,400 m indicated that the minimal stress values were significantly higher, i.e. 1.0 MPa – 1.5 MPa, than the estimated vertical lithostatic pressure.

An exploratory borehole drilled in the area of the Hilltop Farm salt caverns in Cheshire, UK, which are currently converted by EDF from salt winning caverns to gas storage caverns, was used by employing a series of hydraulic/hydrofrac tests to determine the geostatic stress field that characterizes the relevant geological formations. Analysis of the derived geostatic stress gradients indicated that the concept of isotropic geostatic stress field was not a valid assumption for the Triassic salt field in which the Hilltop Farm caverns have been developed, since the horizontal stress components were clearly higher than the respective vertical lithostatic stress. Evidence of anisotropic geostatic stress field (whereby $k_o > 1$) has also been identified in the same Triassic salt field in two other North-West locations in the UK.

Taking into consideration that the horizontal stresses, which essentially provide the lateral confinement to the cemented casing shoe of the cavern's well, were larger than the corresponding vertical stresses, the question which was raised and required further investigations was: can we employ a maximum pressure in the caverns that will be larger than customarily limit of 85% of the vertical lithostatic stress? This paper presents the steps that were undertaken in addressing this question.

Key words: Bedded Salt Deposits, Caverns for Gas Storage, Computer Modelling, Geostatic Stresses, Rock Mechanics, United Kingdom, Cheshire.