Applied Numerical Modeling in Geomechanics – 2020 – Billaux, Hazzard, Nelson & Schöpfer (eds.) Paper: 01-02
©2020 Itasca International, Inc., Minneapolis, ISBN 978-0-9767577-5-7

Convergence-induced stresses on casing and cementation due to salt cavern operation

B. Horváth & D. Zander-Schiebenhöfer
DEEP.KBB GmbH, Hanover, Germany

1 INTRODUCTION

During the operation of salt caverns, the installed last cemented casing will be stressed due to the convergence of the cavern, which results from the creep of the rock salt mass. These additional stresses might lead to a reduction of mechanical integrity followed by leakage and unacceptable fluid migration of storage medium.

At the casing shoe of the last cemented casing, the combined system of casing, cementation and especially the contact interfaces between casing and cementation as well as between cementation and salt rock are of concern in order to withstand the impact from creep deformation over the years.

In order to check whether these stresses induced by creep deformation may lead to a potential loss of integrity, monitoring methods controlled from surface are limited. Thus, numerical models can provide valuable support particularly with regard to the status and development of the well integrity over time.

In a case study for an oil storage cavern the additional subsidence induced stresses have been analyzed applying a *FLAC3D* (Itasca 2017) numerical model, which represents the well including casing and cementation from surface to cavern and the cavern surrounding rock mass (overburden layers and salt). The model further took into account the phases of borehole creation, cementation of casings, and cavern creation to consider relevant stress states. However, the main focus of the study was set to the development of the stressing on the combined system of casing/cementation/salt rock over time of storage operation, which is caused by the creep of salt and the resulting continuous subsiding process.

Induced stresses and strains as calculated by *FLAC3D* were evaluated against stability and/or limiting deformation criteria in order to identify critical states along the access well in the casing, the cementation and the surrounding rock mass.

The evaluation of such numerical simulations is essential for the prediction of the long-term cavern and well integrity and provides the opportunity to adjust operational modes and/or to update maintenance workover plans with the aim to reduce the additional stresses.

2 DESIGN AND ANALYSIS

The detailed cavern model included the simulation of the stress of the last cemented casing due to the continuous subsidence process of the rock caused by creeping of the salt rock. In order to make a reliable assumption for the creep behavior of the salt in the surrounding of the cavern, at first the in-situ creep behavior had to be determined by history matching of the cavern volume over the operating time. For this purpose, the cavern volumes according to sonar measurements were used as matching data. Thus, the in-situ creep behavior of the salt in the area of the cavern could be validated.

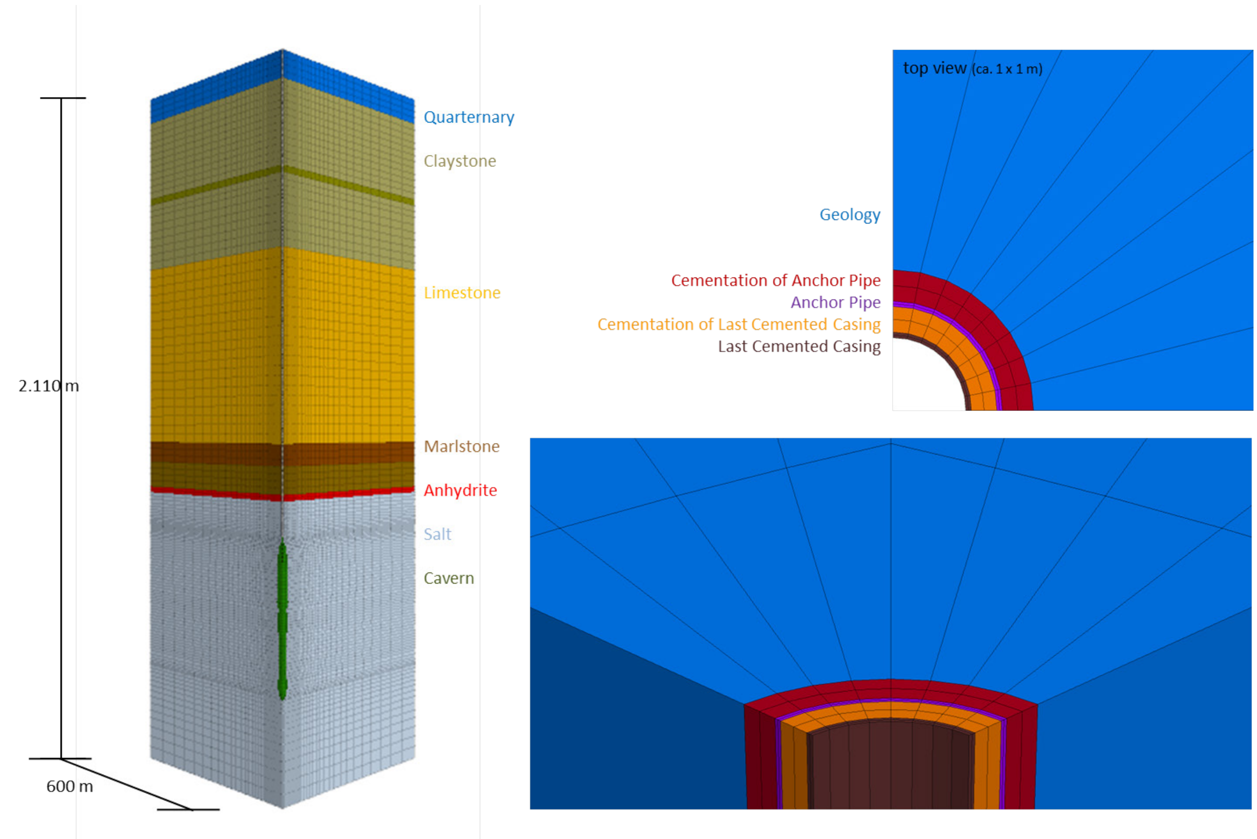

Figure 1. Simulation model.

The applied simulation model represents a quarter-segment section of the rock mass surrounding the cavern. The overburden layers were mapped as horizontal layers. The underlying salt rock was taken into account up to a depth of 2110 m. An oil storage cavern in a depth range between 1300 and 1800 m was considered. Illustrations on the right-hand side of Figure 1 show how the borehole elements were taken into account. From inside to outside, the last cemented casing and its cementation against the anchor pipe (in the overburden section) or below the overburden against the salt rock was taken into account. In the overburden section the anchor pipe and its cementation against the rock mass was additionally taken into account. All borehole support elements were discretized by circular ring elements. The connectors of the casing were not modelled.

The selected outer boundaries of the simulation model do not represent the real pillar dimensions of the cavern field. As a result of the investigations it was concluded that for the analysis of the deformation status close to the wellbore axis and up to the surface a simulation approach had to be chosen, which differs from assumptions that are normally chosen for a stability and tightness investigation in the cavern design phase. Furthermore, essential phase while installing the wellbore elements were discreetly integrated into the numerical simulation.

Since it was the objective of the study to investigate different influencing factors on the stressing of the combined system of casing, cementation and salt rock, a basic configuration of the simulation model was determined with respect to mechanical behavior or material parameters of the overburden layers and the quality of the casings as wells as the cementation of the casings. Thereby, largely realistic estimates of the rock behavior were used, and the assumption was made that the connection between the pipes, their cementation and the adjacent rock is completely intact. In the following variation runs, either a weakening of the surrounding rock area in the focused depth position, or of the cementation quality of the casings or a combination of both were investigated.

3 RESULTS AND DISCUSSION

The results of these calculations did not provide any indication of failure of the last cemented casing in the overburden section, if as failure criterion an exceeding of the plasticity limit of the steel in terms of the von Mises reference stress was chosen. The calculated values for the von Mises reference stress and strain remain in this depth range far below the limit of the plasticity of the material.

In the salt section, the simulation results show that the plasticity limit of the steel was exceeded after 30 years of oil storage, plastic strains of the casing increased with decreasing distance to the depth of the last cemented casing shoe.

However, as steel can sustain relatively large plastic strains this is not inevitably an indicator for failure as wireline measurements of casings after several decades of operations show. The calculated stressing of the cementation also remained below the assumed ultimate strength of the material.

In order to analyze the influence of the creep behavior of salt in the bonding area of casing and cementation an increased creep capability in the surrounding of the borehole was investigated. The calculation results show a reduction of the sinking-induced stress in the last cemented casing, but the calculated values for the von Mises comparative stress still indicate an exceeding of the plasticity limit.

4 CONCLUSIONS

As a result of the numerical investigations of the subsidence induced additional stressing of last cemented casing of access wells of salt caverns the following conclusion were drawn

- According to the creep of salt the stressing of the last cemented casing increases over time.
- After several decades of operation, the last cemented casings can withstand the subsidence induced stressing, if the material characteristics show a pronounced ability for plastic deformation.
- Despite the general statements made above, wellbore integrity of salt cavern wells needs to be assessed on site specific parameters (geology, operation history, material properties, deformation behavior of the materials)
- The behavior of the complex system of casing, cementation and salt in the close vicinity of the wellbore needs to be further investigated especially with regard to the time dependent behavior of the components.
- In order to setup a procedure for wellbore integrity, assessment the joints of the last cemented casings have to be integrated in the simulation model.

REFERENCES

Itasca Consulting Group, Inc. 2017. *FLAC3D – Fast Lagrangian Analysis of Continua in 3-Dimensions, Ver. 6.0*. Minneapolis: Itasca.