วิศวกรรมสารฉบับวิจัยและพัฒนา
Engineering Journal of Research and Development
วิศวกรรมสถานแห่งประเทศไทย ในพระบรมราชูปถัมภ์
The Engineering Institute of Thailand under H.M. The King's Patronage
ปีที่ 28 ฉบับที่ 2 เมษายน-มิถุนายน 2560
Volume 28 Issue 2 April-June 2017
Received 16 March 2017
Revised 25 April 2017
Accepted 2 May 2017

EFFECTS OF BACKFILL COMPOSITIONS ON INTEGRITY OF UNDERGROUND SALT AND POTASH MINES

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ABSTRACT

The objective of this study is to laboratory investigate the effects of various backfill compositions on the integrity of rooms and pillars in salt and potash mines. Uniaxial creep tests have been performed on halite and carnallite core specimens for up to 21 days. A total of 20 specimens have been tested. The constant axial stresses are varied from 2 to 12 MPa. After the specimens are under loading for 7 days, they are separately submerged in three types of solutions prepared from halite, carnallite and magnesium chloride. The solution is removed after 7 days. The visco-plastic coefficients are calculated for each phase of solution submersion. They are used as an indicator of the sensitivity between the tested specimens and the types of solution. The results indicate that the specimens that are composed of pure halite is insensitive to these solutions, as evidenced by that the creep strain rates measured before, during and after brine submersion remain unchanged. The specimens containing carnallite of 30% to 90% by weight are sensitive to halite and carnallite solutions, but insensitive to magnesium chloride solution. The percentage weight loss of the carnallite specimens during submersion in these solutions confirm that saturated magnesium brine has insignificant effect on the dissolution of the carnallite specimens. The findings can be used for the material selection and the performance assessment of the installed backfill compositions in salt and potash mines.

KEYWORDS: Halite, Carnallite, Creep, Backfill, Magnesium Chloride

1. Introduction

Backfilling materials as a slurry may affect the stability and integrity of salt and potash pillars and sidewalls in the mines because the installation process may use solutions as a composition. Humidity and moisture may also affect salt creep deformation and strength. Moisture and brine around the pillars may change they axial, radial, and volumetric strain rates, and hence affects the salt creep deformation and strength [1]. Creep of halite is affected by humidity of the surrounding, especially above 75% R.H. Higher humidity induces a higher rate of deformation [2]. The quantitative effect of humidity and brine, however, has rarely been determined due to insufficient laboratory and field measurements.

Potash and salt mines have commonly used the salt tailing as backfill to reduce the mine waste and to control the surface subsidence. This is due to its availability and low cost. Several geologic materials are also considered as parts of backfill compositions. These include, but not limited to, bentonite, clay, silt, sand, gravel, crushed rocks, mine wastes and cementitious materials [3-5]. The backfill materials also include some types of liquid to enhance bonding between these particles after emplacement and for an ease of transportation and installation processes. Careful selection of liquid types and amounts should be taken to ensure the long-term chemical compatibility between the backfill compositions and the surrounding host rocks. The chemical compatibility between the host rocks (salt and potash) and the backfill compositions however has rarely been studied and verified.

The objective of this study is to experimentally determine the effects of halite, carnallite and magnesium brines on the time-dependent deformation of salt and potash specimens obtained from the Maha Sarakham formation. Uniaxial creep testing has been performed on rectangular blocks of specimens obtained from a potash mine in the northeast of Thailand. A total of 20 specimens has been tested for up to 21 days. The creep strains are monitored and used as an indicator of the effect of the halite, carnallite and magnesium brine on the tested specimens.

2. Sample Preparation

The tested samples have been obtained from underground openings of ASEAN Potash Mining Co., Ltd. (APMC). They belong to the Lower Salt member of the Maha Sarakham formation. Warren [6] describes the origin and geological structures of the Maha Sarakham salt. The samples contain mixture between halite and carnallite. An attempt to obtain cylindrical cores has been made in the laboratory. During drilling the cores with high carnallite content tended to break along the bedding planes, particularly at the interfaces between the carnallite and halite. The specimens used for the uniaxial creep tests are therefore prepared as rectangular blocks with nominal dimensions of 54×54×108 mm^3. A high speed rock cutting device is used. Organic oil is used as cutting fluid. Figure 1 shows some examples of the rectangular blocks specimens prepared for creep testing.

Three types of brine are used in this study: halite, carnallite and magnesium brines. The halite brine is prepared by mixing distilled water with pure sodium chloride (NaCl). Pure carnallite ($KMgCl_3 \cdot 6H_2O$) obtained from a potash mine is used to prepare the carnallite brine. The magnesium brine is prepared from pure magnesium chloride ($MgCl_2$) mixed with distilled water. All three solutions are under saturated condition. The preparation and testing are performed under ambient temperature (25 °C)

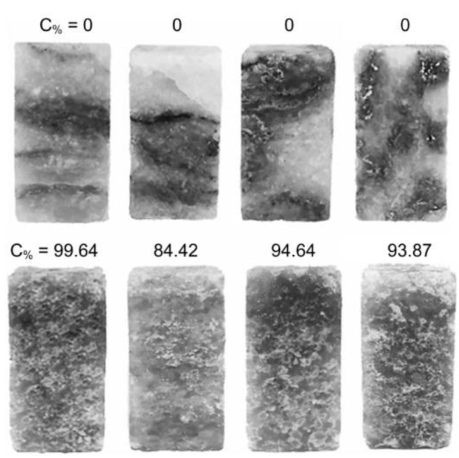

Figure 1 Some specimens (54×54×108 mm) prepared for creep testing under dry and submerged conditions

3. Creep Test Apparatus and Method

A consolidation load frame [7] has been used to apply constant axial stress to rectangular specimens (Figure 2). It has been used in this study because the cantilever beam with pre-calibrated dead weight can apply a truly constant axial stress to specimens. Pre-calculated dead weight loading devices are used to apply constant axial loads to the specimens. Except the specimen shape the test procedure follows, as much as practical, the American Society for Testing and Materials [8]. Neoprene sheets are placed at the interfaces between the loading platens and specimen surfaces. Each specimen is tested up to 21 days. After the specimens are under loading for 7 days, they are submerged in saturated brines prepared from halite, carnallite and Magnesium chloride. Then the solution is removed after 7 days. The axial deformation is continuously monitored using displacement digital gages. They are used to calculate the axial strains of the specimen. The readings are made every one minute for the first hour. After that the reading interval are gradually increased to every hour. The specimens are tested under the axial stresses from 2, 4, 6, 8, 10 to 12 MPa. The tests are conducted under ambient temperature (25-28 Celsius).

4. Test Results

In order to quantitatively determine the effects of the three different submerging solutions on the creep deformation of the specimen, the visco-plastic coefficients (η_1) during each phase of testing are calculated using:

$$\eta_1 = \sigma_o / \dot{\varepsilon} \tag{1}$$

where σ_o is the constant stress apllied to each specimen (MPa) and $\dot{\varepsilon}$ is the strain rates within the steady-state creep phases before, during and after submersion. The visco-plastic coefficients will be used as an indicator of the effects of the solutions on the creep deformation of the specimens during loading. Table 1 summarizes the results, suggesting that the creep rates of pure halite specimens are not affected by the three brine solutions. The potash (salt with carnallite contents) specimens are however highly sensitive to the solutions prepared from the saturated halite and carnallite brines. They fail almost immediately after submersion in these two solutions. Under saturated magnesium brine however the creep rates of the potash specimens do not vary with the conditions before, during and after solution submersion. Figure 3 shows examples of the axial strain−time curves for all salt specimens. The curves show the instantaneous, transient and steady-state creep phases of the specimens. No effect of the brine submersion has been detected. This is suggested by the fact that no change in creep rate is detected before, during and after halite brine submersion. The potash specimens (Figure 4) fail after submersion under halite and carnallite brines probably because the specimens can dissolve in these brines, and hence accelerates the creep rate and eventually reaches the tertiary creep phase (toward failure).

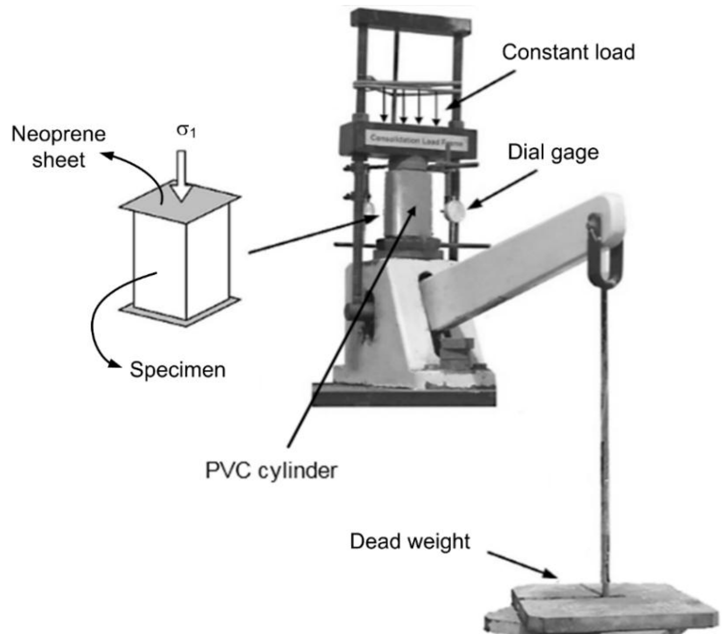

Figure 2 Consolidation load frame used for creep testing of salt and potash specimens. Specimen is set in water-tight PVC cylinder for submerging solutions during loading

Table 1 Visco-plastic coefficients measured before, during and after submersion in different solutions

Specimen Type	Type of Solutions	Visco-plastic Coefficient (η_1) (GPa.day)		
		Before Submersion	During Submersion	After Submersion
Salt	Halite Brine	22.02 ± 3.65	22.02 ± 3.65	22.02 ± 3.65
	Carnallite Brine	22.12 ± 6.28	21.60 ± 6.48	26.29 ± 2.75
	Magnesium Brine	24.32 ± 3.65	23.15 ± 4.05	27.06 ± 0.89
Potash	Halite Brine	5.98	Fail	Fail
	Carnallite Brine	5.62 ± 0.57	Fail	Fail
	Magnesium Brine	19.23	19.23	19.23

5. Weight Loss Testing

An attempt is made here to further confirm the effects of carnallite contents on the creep deformation in the previous section. It is postulated that the increase of strain rate or decrease of the visco-plastic coefficients during solution submersion of the specimens containing carnallite is primarily due to the dissolution of the creep specimen perimeter. This results in a decrease of the cross-section area of the specimens, and hence its axial stress is increased while under the same loading magnitude. To verify this postulation a series of weight loss testing has been performed. The specimens (54×54×108 mm) with carnallite

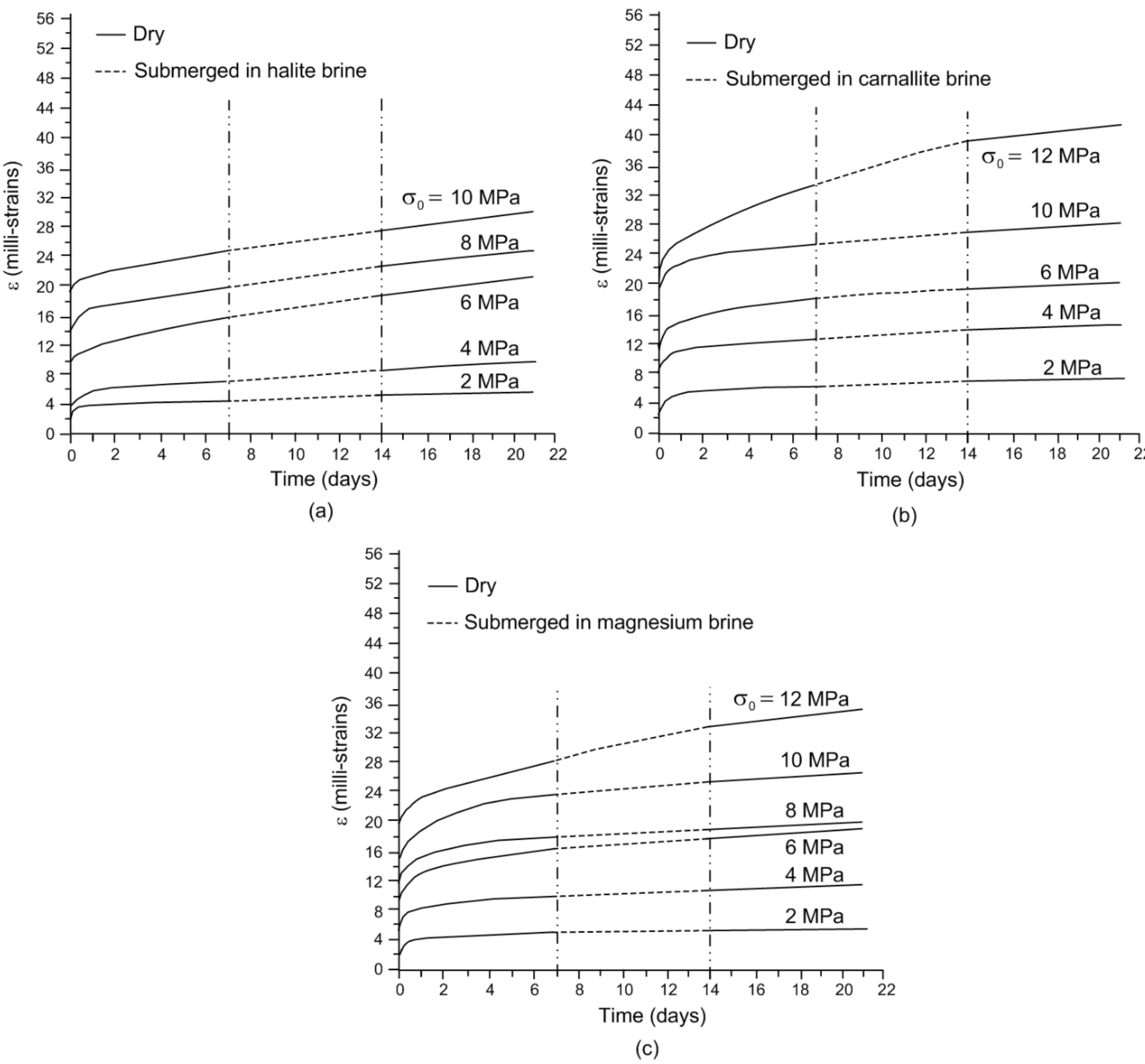

Figure 3 Strain-time curves obtained for creep testing of pure halite submerged in halite brine (a), carnallite brine (b) and magnesium brine (c)

contents ($C_{\%}$) varying from 0 (pure halite) to 91% are separately submerged in the three different solutions for 7 days. Their weights are measured daily to the nearest 0.1 g. The weight loss is calculated by:

$$\text{Weight Loss} = [(W_o - W_i)/W_o] \times 100 \quad (\%) \qquad (2)$$

where W_o is the initial weight of specimen and W_i is the specimen weight during submersion each day.

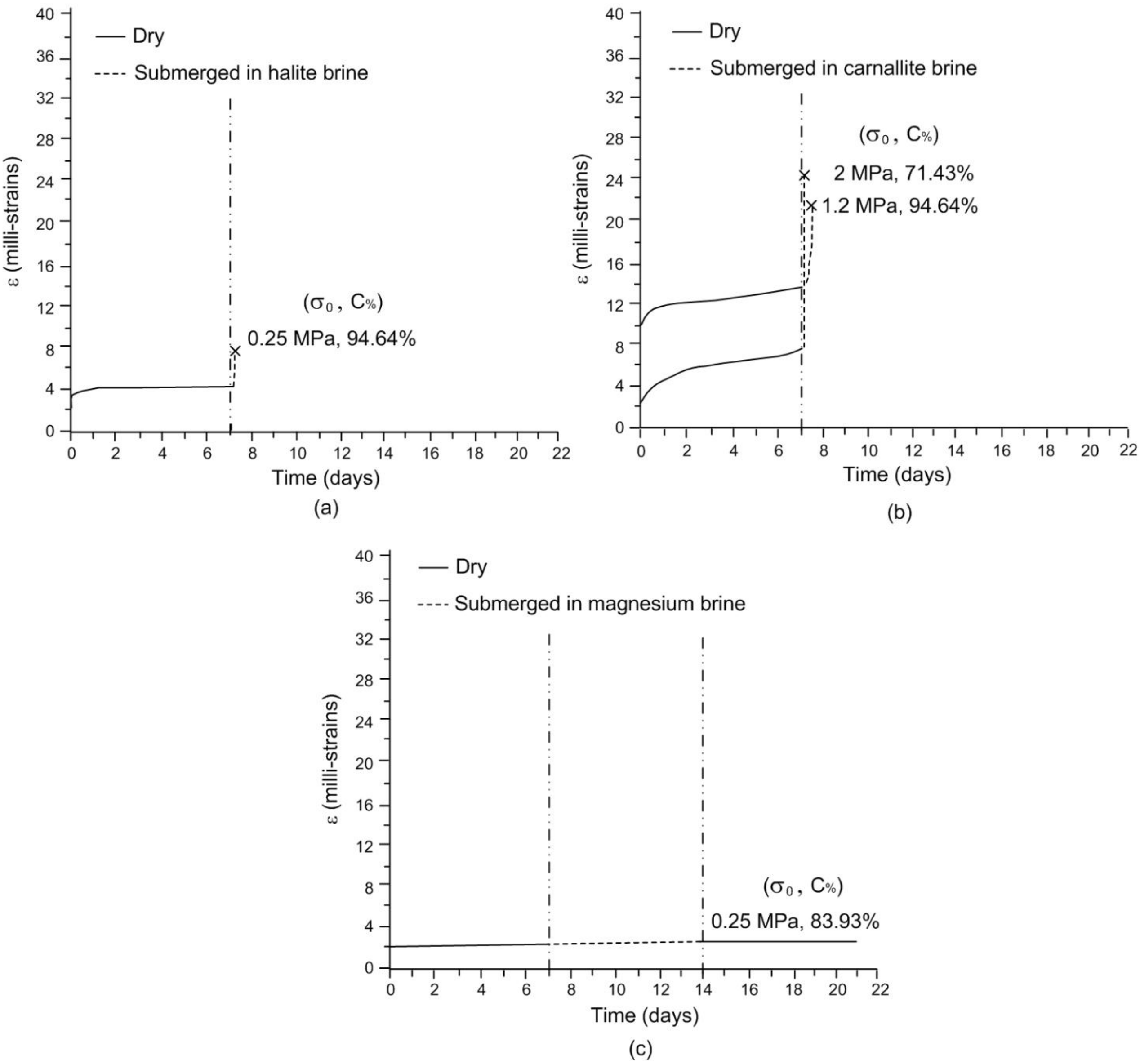

Figure 4 Strain-time curves obtained for creep testing of potash submerged in halite brine (a), carnallite brine (b) and magnesium brine (c)

Figure 5 plots the weight loss as a function of time for each specimen under different submerging solutions. It is clear that pure halite specimens ($C_{\%}$ = 0) is insensitive to the three solutions. The percentage of weight loss is largest when the potash specimens are subjected to halite solution (Figure 5(a)). The saturated magnesium brine tends to have insignificant effect on the specimens even for those containing carnallite up to 91% (Figure 5(c)). The solution prepared from carnallite can notably dissolve the specimens, and leads to the weight loss of up to 20% for specimen containing carnallite of 91%. In summary the specimens with higher $C_{\%}$ tend to lost more weight than those with lower $C_{\%}$. This is true for all submerging solutions.

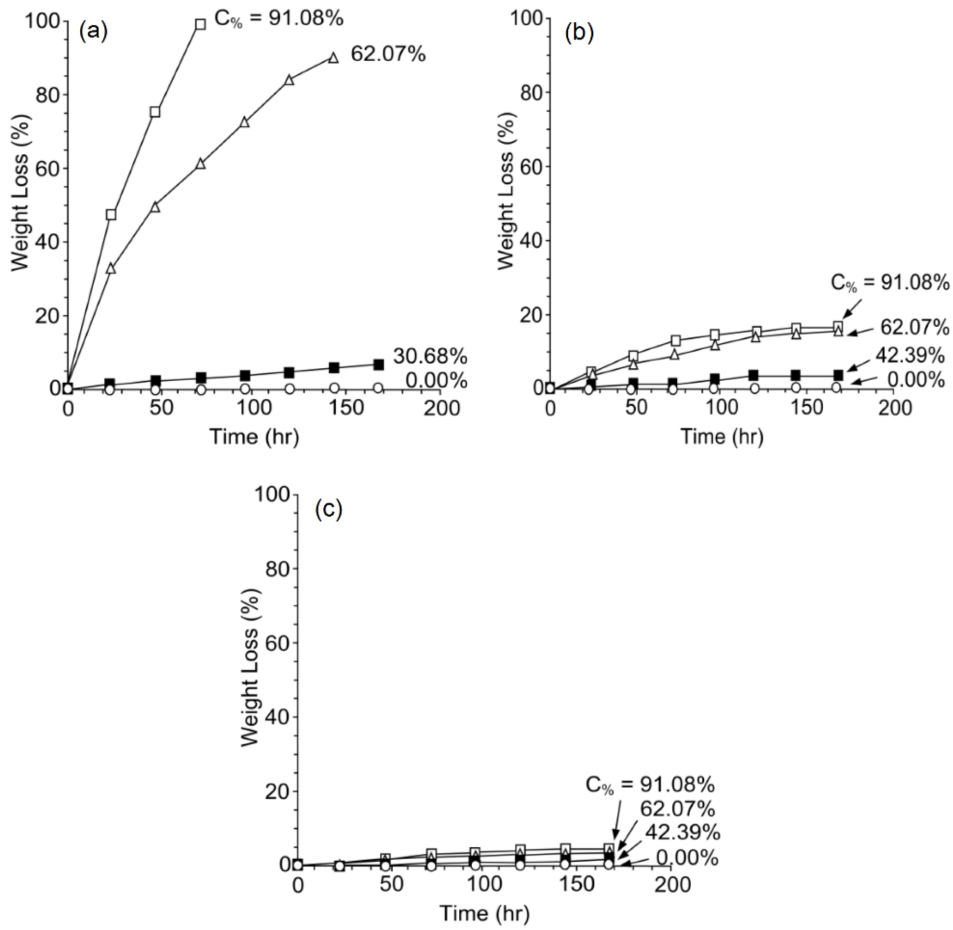

Figure 5 Weight loss (%) of the carnallite specimens as a function of time, under halite brine (a), carnallite brine (b), and magnesium brine (c)

6. Conclusions

The results from this study can be concluded that the pure rock salt ($C_{\%}$ = 0) is insensitive to the halite, carnallite and magnesium brines. The specimens containing carnallite of 30% to 90% by weight can be dissolved in halite and carnallite brines, but tends to be inert to magnesium brine. These weight loss testing results agree with the creep testing results that magnesium brine may be the most suitable candidate to mix with solid particles to form backfill materials for the openings surrounded by carnallite. The halite and carnallite brines should be avoided for sealing or backfilling of the carnallite openings. For the openings in pure rock salt all these solutions can be used as a mixing component for the backfill material. This is evidenced by the fact that rock salt is insensitive to these solutions (Table 1) as long as they are under saturated condition.

Acknowledgements

This study is funded by Suranaree University of Technology and by the Higher Education Promotion and National Research University of Thailand. Permission to publish this paper is gratefully acknowledged.

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